JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

Vol. 39 | November 1947 | No. 11

Water Main Extension Policy

By W. V. Weir, M. P. Hatcher, J. H. Murdoch Jr., E. F. Dandridge, L. S. Finch and C. M. Hoskinson

A panel statement presented on July 21, 1947, at the Annual Conference, San Francisco, by W. V. Weir, Pres., St. Louis County Water Co., University City, Mo.; followed by a symposium participated in by M. P. Hatcher, Director, Water Dept., Kansas City, Mo.; J. H. Murdoch Jr., Atty., American Water Works & Electric Co., New York; E. F. Dandridge, Chief Clerk, Dept. of Water and Power, Los Angeles; L. S. Finch, Chief Engr., Indianapolis Water Co., Indianapolis, Ind.; and C. M. Hoskinson, Supt. and Chief Engr., Div. of Water and Sewers, Sacramento, Calif.

Statement by the Panel

EQUITABLE rules for the financing and installing of water mains to supply new customers should treat simply and in proper detail the various phases of extension policy in nondiscriminatory fashion:

1. Extension rules should not favor new customers so greatly that extensions of mains will increase, or tend to increase, the cost of water service to existing customers. It is the latter who have enabled the new customers to obtain water service at reasonable cost, because old customers have developed the water works plant and distribution system through their water rate payments and contributions.

2. New customers should be able to obtain water main extensions and water service at the lowest reasonable cost. The growth of the community should be encouraged by fair extension rule provisions, but not by subsidization.

3. Generally, revenue from a new customer should exceed the cost of supplying water, including the carrying charges on the plant, general property and the large mains used in serving

him. The utility's investment in a water main extension to serve a new customer should be based on the portion of the revenue available to cover carrying charges on such an investment.

Application of Rules

One basic rule applying to all extensions is believed most equitable, although distinct classes of new customers may require separate sections or, possibly, entirely separate rules.

Authorization of Rules

Private utilities must necessarily obtain regulatory commission approval of their rules, which are thereafter to be followed without deviation. Municipal utilities should have extension rules approved by the water board or city council so that the utility management can enforce them uniformly, regardless of outside pressure.

Provisions

Extension rules should include comprehensive statements covering each of the various points upon which the utility and the party wishing a main extension must have an understanding.

Determination of Pipe Size

The utility should determine the size and type of pipe to be used in each extension. If the utility wishes the pipe to be larger than that reasonably required to serve the territory traversed by the extension (usually up to 6 in.) the excess cost of the larger pipe should be borne by the utility.

Extension Cost Estimate

The utility should make an estimate of the total cost of installing the pipe. Unless the utility follows the practice of contracting for extensions on an average unit-cost basis, the utility should refund to the extension promoter any overpayments he makes based on the estimated cost. The utility should absorb any excess of actual cost over estimated cost.

New Customer Pays for Extension

The new customer or the real estate developer should pay the utility in advance a portion of the cost of the extension equal to the estimated cost less any investment the utility may make because of the revenue it will receive.

Refunds and Allowances

Unless the utility has a stated policy of assessing the frontage along a new extension for the cost of the extension, as is practiced by a number of municipal utilities, the utility should state the basis upon which it will make its investment in the new extension. This investment may be in the form of (1) an initial allowance of a stated number of feet of pipe per customer immediately connecting to the new extension or (2) refunds for any additional customers connecting within a given period. These refunds should be based upon the cost of a stated number of feet of pipe per additional customer or on a stated number of dollars for each dollar of annual revenue received. The total of initial allowances and subsequent refunds should not exceed the amount paid to the utility for the new extension.

Refunds made for additional customers connecting to a new extension should be limited to a stated period, preferably not exceeding ten years after the installation of the main. The utility must ultimately replace the pipe installed. If the utility has not received sufficient revenue in a ten-year period to warrant assuming the full investment in that time, no additional investment

should be made. It is doubtful whether such a low-revenue extension would allow the utility to accumulate enough money for replacement reserve to prevent the new extension from becoming an economic burden.

Because the money advanced by an extension promoter is paid out for the expenses of installation, any unrefunded balances do not represent income-producing assets of the utility. No interest, therefore, should be paid on these balances.

Title to Extension

The ownership title to an extension should always be vested in the utility, regardless of promoters' advances or unrefunded contributions. The utility must undertake the maintenance and the ultimate replacement of the pipe. The utility must have full control over the main, including the right to connect additional customers without the consent of the promoter.

Status of Further Extension

The utility should have the right to make additional extensions of a water main beyond or laterally from the initial extension. Further extensions should not be considered as additional connections to the extension and therefore should not be the basis for additional refunds to an extension promoter.

Private Mains Prohibited

Private lines in lieu of utility water mains should not be permitted. Water connections should not be made to the pipes supplying the premises of a customer unless a water main is, or will be, extended to a point contiguous to them. Any extension of a water pipe down a street or way used by the public should be installed under the terms of the utility's extension rule.

Review of Extension Rule

Changing conditions, such as increased cost of service or installation, may cause an extension rule to become discriminatory. The terms of extension rules, particularly those pertaining to investment formulas, should be reviewed periodically, possibly every five years. Revisions should be made as required to keep the extension rules fair to both old and new customers.

Contract Form

Each applicant for a water main extension should be tendered a proposal on a standard form describing the extension and giving the amounts of payments which must be made to the utility, the allowances for initial new customers and the refunding provisions for subsequent customers connecting, as well as detailing the other provisions discussed above.

Symposium

Melvin P. Hatcher

The crux of the water main extension problem lies in a determination of the amount—in dollars or length of pipe—that the utility itself can afford to contribute toward the cost of the extension. This requires a statement of the principle that is to govern such a determination. In this writer's opinion, the panel statement includes the best possible definition of that principle: *that the water main extension policy should not have the effect, even theoretically, of causing an increase in the cost of service to existing customers.* If a particular water main extension fails to return revenue suffi-

cient to cover the cost of service to those attached to the extension, then existing customers of the water works system making that extension must bear the burden of the revenue deficiency.

If the principle that has been defined is adhered to, the measure of the utility's contribution to a water main extension will be affected by its operating expenses, its rates for service, and the compensation required for the use of capital. It is clear that a water main extension for one property may not be suited for use by another, and it is equally clear that the policy for any one utility should be reviewed from time to time. The writer would supplement the basic principle mentioned, that extensions should not increase the cost to old customers, with the provision that it should be liberally interpreted and applied by publicly owned water works properties. In other words, the utility should contribute the most that it can without violating the main principle.

Kansas City Extension Policy

Kansas City water main extension policy has been evolved with this thought in mind and reflects a consideration of the incremental cost of service to new customers as opposed to the average cost of service for all customers. The reasoning on this point is somewhat as follows: It costs less to serve a new customer using a certain amount of water than it does to serve the average existing customer with the same water requirements. It requires less pumping and purification plant labor *per customer,* for example, to serve 40,000 customers than it does to serve 30,000. Other expenses, however, like power for pumping and chemicals for purification, are very nearly proportional to the amount of water pumped and treated. Taken as a whole, however, the cost of service to the new customer is less than the cost of service to the existing customer. The new customer can therefore be given credit for this cost-of-service advantage without violating the basic extension principle.

It should be possible to determine this incremental cost of service for any class of customers. To do so with complete accuracy might require a comparison of all subdivisions of expense for existing customers with a

TABLE 1

Kansas City Annual Water Costs per Customer

	Average	Incremental	Total
Customer Cost	$2.95		$2.95
Commodity Cost	1.55	$1.60	3.15
Fixed Charges			
Plant and trunk mains	3.25		3.25
Secondary mains		2.65	2.65
TOTALS	$7.75	$4.25	$12.00

parallel estimate for an increased number of customers. The use to which the result is to be put, however, hardly seems to justify such refined calculations. A reasonably close estimate of the difference between average and incremental cost can be made in a simpler way. By grouping costs of service according to the way they vary with the number of customers served or with the quantities of water used, it can be shown that the additional cost of serving the new customer is less than the average cost of serving existing customers. The viewpoint that is provided by an analysis of this kind seems accurate enough for the purpose.

Kansas City's water main extension contribution of $120 for each customer expected to use $12 worth of water per year is predicated on a calculation of this sort. The mechanics of the calculation may be illustrated from the summary in Table 1 of the costs of serving that customer.

The "average" column includes those costs which are assumed to be directly proportional to the number of customers served or to the amounts of water used. "Average customer cost" comprises all meter reading, billing, collecting and turn-on and turn-off expenses; "average commodity cost" includes only coal and power for pumping and chemicals for purification. "Incremental commodity cost" is that part of the operating expenses relatively unaffected by the addition of customers. The $2.65 portion of fixed charges is that portion of the total revenue derived from existing customers which is chargeable to secondary mains. On the basis, then, of 3.5 per cent for interest and depreciation on secondary mains, the capitalized value of $2.65 per year at 3.5 per cent, or about $76, is the amount that Kansas City can afford to contribute toward a main extension to serve a new customer if the incremental cost feature is overlooked. Taking the $1.60 incremental element into account, the total contribution that can be made becomes the capitalized value of $4.25 per year at 3.5 per cent, or $121.

Although the result is close to the actual amount used in the main extension plan, these calculations need not be adhered to strictly. They do appear to demonstrate, however, that Kansas City's plan has a sound foundation and that the range within which the decision should be made certainly lies between $75 and $120 per customer.

The Kansas City main extension plan includes the provision that the full amount deposited against the extension will be refunded when the total revenue from customers connected to it equals or exceeds 10 per cent of the cost of the extension in any twelve-month period within ten years from the date of the contract. This is, of course, another liberal interpretation of the conclusion drawn from the calculation in Table 1.

The writer disagrees with that part of the panel statement which provides that the utility should absorb any cost over the estimated cost. Kansas City contracts call for no refund until earned refunds have compensated for any such discrepancy. Under the provision included in the panel statement, it is likely that the utility would be continually importuned to make low estimates of cost. It seems proper for the main extension plan to be based finally on actual rather than estimated figures. By the same token, the customer or the builder has a right to expect that the work will be done at reasonable cost.

John H. Murdoch, Jr.

The panel statement should be extensively studied and discussed by this Association in order that a sound policy may be adopted as a guide for the industry. One feature of the suggested policy which the writer desires to stress is the principle that extension rules should be drawn so that new customers will not be favored at the expense of existing customers. If that principle is firmly established and understood, the necessary details of ap-

plication, with desirable variations, become relatively simple. It should be insisted that each of the customers pay a share of the entire cost of the service, not merely the incremental cost of his particular service. Unless this is done, extensions will be installed at the expense of the utility if the prospective revenue is sufficient merely to cover the capital carrying charges on the main extension. The new customer under such conditions makes no payment toward the cost of delivering the processed water to the new extension and becomes a "free rider" at the expense of the existing customers.

It is the interest of the existing customers which is to be guarded, not the interest of the utility. The experience of individual water utilities shows that in normal times a nearly constant proportion of each dollar of revenue from customers is expended in operations. Existing customers are therefore entitled to assume that the same percentage of the revenue to be received from a new extension will be used to meet operating expenses. Experience in normal times also demonstrates that a fairly constant proportion of all revenue received is required for capital carrying charges on supply, treatment and transmission works. The same percentage should be applied to these items out of potential revenues from the new distribution main. Only after the prospective revenue has had these two percentages charged against it does the amount of money remaining become available for capital carrying charges on the new main.

Sound application of this principle will result in extension rules which are fair to all customers, both existing and prospective.

Ernest F. Dandridge

It has often been said that everybody talks about the weather but nobody does anything about it. The same remark might be made about water main extension policies. Many papers have been presented on this matter at national and regional meetings of the Association. Some have related what is being done in various places throughout the country. Others have offered constructive approaches to the solution of the problems inherent in the subject. All of this activity has resulted, through publication, in creating a background of information from which standard procedures should be laid down.

The A.W.W.A. has a number of active committees in the water works practice group which have produced notable results. Standards of water works materials have been drawn, or are being considered, which can be used by the individual utility with assurance, making individual experimentation unnecessary. Thus a composite of the best knowledge, skills and techniques gained through experience by all water systems is presented in one valuable package and handed to the entire industry without cost.

Water works administrators are all reaching for a package containing standards for use in determining water main extension policy. Those standards can best be obtained through collective action by setting up a water main extension policy committee to establish a standard or recommended practice. Such an assignment will not be easy to complete, but neither were the assignments given those who have produced standards in other fields. The task can, and undoubtedly will, be accomplished. The question is *when?*

The statement by the panel represents the area of agreement which could be found among its members, who were hampered by their inability to meet for extended discussions. The statement is not intended to be complete, but rather to serve as a starting point from which further progress can be made. The next step is the appointment of a committee to carry on the work that everyone agrees will be of tremendous value to water works utilities. Once standards are available, it will be easier to modernize extension policy. Inertia will be overcome by the desire to make local policy conform with the general specifications as far as conditions permit.

Los Angeles Extension Policy

Since 1941 the author has had the responsibility of administering the extension rules for the Los Angeles Water Dept. It soon became apparent that these rules were in need of revision if the system was to be extended on an equitable and economically sound basis. Study of the problem was ordered in December 1942 and has been continued intermittently ever since.

The Los Angeles extension rules were established in 1920. The theory behind them was that the customer should contribute the full reasonable cost of the distribution system fronting his property. A flat charge per foot of frontage was fixed which was based upon the average installation cost of 4- and 6-in. pipe.

At that time the department was heavily tax-supported, and rates for water service were relatively low. Since then the factors to which the extension policy is so closely related have all changed. Tax support has been discontinued; water rates have been increased; costs of construction no longer stand comparison with those of 1920; and system design now calls for the installation of 6- and 8-in. pipe. The result is that the extension policy has been changed without changing the rule.

Although it is still said that nobody does anything about the weather, the statement is no longer true. Many people have moved to Los Angeles because of its weather. This movement has contributed heavily to the present population of 1,900,000—an increase of 1,323,000 over 1920. In 1920 the water system included 1,489 miles of water mains; today the total is 4,427 miles. Since 1920, when the present rule was established, the pipe system has grown to three times its size by the addition of 2,938 miles of pipe. During the last year 61 miles were added. Of course, some of the additional mileage represents trunk lines which are not covered by the extension rule, but this is only a small portion of the total.

Examination of the problem gives rise to the question whether the rule should be changed to re-establish 1920 policy. Such a move does not seem to be in keeping with the modern practice by which rates are fixed at a level sufficiently high to provide a free extension of reasonable length. Tests have been made of the provisions of a proposed new rule involving a cost guarantee returnable on the basis of a percentage of revenue received in ten years. It is indicated that at present rate levels there would remain an unrefunded balance approximately equivalent to the flat charge of the present rule. Such a provision, however, would reduce to a minimum the financial hazard which is so great under the present system.

It would be advantageous to be able to check the proposed new rule against a "standard" based on nation-wide experience and experimentation. It would then be possible to judge with greater assurance whether the rule is fair and workable. Pooling the results of experience, experimentation and studies will give the entire profession the benefit of all present knowledge. It is time now to convert talk about the water main extension policy into co-operative action leading to the best solution of a problem common to all water utilities.

Lewis S. Finch

The problem of determining when it is feasible to extend water mains to serve new customers merits careful study, especially because there often is no obvious or universally applicable solution. Each utility is faced with questions which, though generally similar to those encountered by other utilities, nevertheless must be answered by specific rules conforming to certain broad principles. It is almost axiomatic that the new customer must pay his own way and not become a burden upon existing customers. If this principle is accepted, the problem then resolves itself into calculating whether a proposed extension will pay for itself and, if it will not, into devising means by which the prospective customers can assist in defraying the cost.

Uniform Policy

Emphasis should be given to the principle that one basic rule must apply to all extensions, although different classes of new customers may require separate sections or even entirely separate rules. One of the most difficult problems is presented by prospective customers living on a street already partially built up but not to the extent that the anticipated revenue would be sufficient to warrant a main extension. Under such circumstances, where front-foot assessments are not used to defray part of the cost of construction, the utility usually requires deposits which are subject to later refund as additional business develops. Difficulties arise, however, in collecting and refunding the deposits of individual customers on a street. No means is available for requiring that all participate alike in sharing the financial burden of making the required deposit. Moreover, the utility is faced with the fact that many small deposits and contracts will necessarily be required, adding to the routine of keeping accounts and making refunds as new customers come upon the line. To complicate this situation further, water service often is needed desperately in sparsely built areas where the economic status of the potential customers is such that they cannot advance the necessary deposit.

If a new subdivision is to be served, or a developer is building a large number of houses along an existing street, the extension problem is greatly simplified. The builder or developer can make the necessary deposit, and the utility will have only one, or, at most, two or three parties to deal with.

Obviously, the same rules cannot be made to apply to these two classes of prospective customers. Nevertheless, as stated in the panel report, the utility must adhere to the basic principle that new customers pay their own way and that the same yardstick be used in determining the required deposits.

Determining Utility Investment

The extent to which a utility should invest in new extensions depends on

three general considerations. First, the new customer should pay his share of the expense of producing the water which he uses. Second, he should pay his fair share of the necessary return upon the utility's investment in the equipment and facilities devoted to producing this water. Finally, he should pay enough to yield a return on the facilities directly serving him.

The cost of the water actually used by the customer can be determined through information available in the accounting department of the utility. Operating expenses, depreciation and taxes are the items which should be included. If these costs are computed upon a unit basis, that is, the cost per million gallons, the amount chargeable to the production of the water actually used can readily be obtained.

Likewise, it seems proper that the return upon the investment in the part of the plant devoted to producing and distributing the water could well be apportioned in the ratio that the water used by the customer bears to the entire output of the plant. In determining such costs, only the value of transmission and primary distribution mains should be included.

After the two foregoing demands have been satisfied, the balance of the revenue from the customers on the extension can be capitalized to determine how much of the cost may be borne by the utility. Construction expenses over and above this capitalized cost should be borne by the customer.

Contract Form

It has been stated in the panel report that, when deposits are required, the utility should contract with the prospective customer or developer sponsoring the extension. No form of contract prepared for use by one utility can be applied without change by another, but it appears desirable to present a general form for such a contract. This form can serve as a model for those developing their own contracts.

The appendix to this symposium contains a draft of a contract which appears to be flexible in its application. Certain general provisions are set out as standard conditions, and space is provided for entering special conditions which apply to the individual job. No brief is held for the content of this draft, but it is believed that most of the items presented should be included in every actual contract. Obviously, details must conform with utility commission requirements and provide proper return.

Attention especially is called to item No. 6 of the standard conditions. This is not of extreme importance in the administration of main extension policies, but it will be found quite helpful if it becomes difficult to locate parties to whom refunds should be made. In the absence of such a provision, the utility may have to carry a considerable sum upon its books which it would like to clear from the records. The inclusion of this stipulation in the standard conditions would thus relieve an accounting headache.

Carl M. Hoskinson

A basic and comprehensive set of rules for all phases of water main extensions should be promulgated by the board or council governing the utility and published as a fixed policy. Such rules should include, directly or by reference, all the standards for materials and construction which have been adopted by the utility and approved by its governing body. If these rules are adhered to without deviation, they will do much to reassure the customer.

Original extensions into subdivisions should be paid for by the property benefited. Construction should be undertaken at cost by the utility, which should be in a position to perform the work at the most reasonable figure. Feeder mains serving more than one area should be installed by the utility and paid for from operating revenue. After an extension is built, the cost of its maintenance and repair should be borne by the utility as an operating expense. For this reason, the quality of material in any extension should be so good that no replacements will be needed for a minimum of at least 25, but preferably 40 or 50, years.

If the utility elects to make a "free" extension, it should not pass beyond the limits of the street, alley or other property on which the utility has a perpetual right of way or easement. Any free extension provided at the utility's expense should have its value assessed on the basis of revenue expected from the customer.

The utility should by all means retain full title to all pipe served by it on any public street, alley, road, right of way or easement provided for the installation and maintenance of the pipeline. When any line serving a single customer is entirely on his private property, the pipeline should be furnished, installed and completely maintained by the customer, but subject always to utility and health department rules for maintenance in good condition and free of contaminating influences.

Costs of extension should be paid in advance by the customer or real estate developer. When an extension is so financed, the amount paid by the customer should be adjusted to the actual cost to the utility. The estimated cost advanced by the customer should satisfy the utility even though the actual cost may be a few per cent higher. Requests for additional payments are not conducive to good will. If the actual cost is materially less than the estimate, a refund should be made. In general, a fixed price without increase or refund is considered most satisfactory.

If a contract is made with a customer or real estate developer calling for later refunds, the simplest and most equitable plan is the best. Usually a refund based on the connection of additional consumers is desirable. Refunds may be planned on a fixed percentage per customer, based on the ratio of customers connected, to the total possible connections to the extension. Refunds should not be made for a period longer than ten years, because conditions will probably change and the subdivision or area should be developed to its maximum income possibilities within that time. If it has not been so developed, it is probable that the utility is not receiving revenue sufficient to repay its investment in primary and feeder facilities.

By its interpretation of the extension rules and standards, the utility should have full control over the size and type of pipe and equipment to be allowed. When pipe larger than that needed for a particular extension is required by the utility in order to serve another area, the extra cost should be paid by the utility.

Private lines should not be permitted or recognized on streets, alleys, roads, rights of way or easements. If installed in such places, they should be the property of the utility, which should maintain them as part of its system. Endless trouble usually develops when the utility serves so-called private lines to which unauthorized consumers may be connected without its knowledge.

APPENDIX

Contract Form

Application and Agreement for Water Main Extensions

· The undersigned Applicant is desirous that water service from Water Company mains be made available to serve the following streets:

1. .... from .... to ....

2. .... from .... to ....

To induce the Water Company to lay the water main necessary to serve the said streets as indicated, the Applicant agrees to the "Special Conditions" and "General Conditions" hereafter set forth and in consideration thereof hereby deposits with the said Water Company the sum of

.................dollars and..........cents ($............).

It is understood and agreed that the aforesaid deposit is made subject to the following Special and Standard Conditions:

Special Conditions

1. It is understood that the amount of said deposit is equal to the sum of ....dollars and..........cents ($............) per linear foot for..........ft. of main required, less credit for..........anticipated customers in the amount of.................. dollars and..........cents ($............) for each such customer. The addresses of the anticipated immediate customers are:

....

....

2. It is understood that no refunds, as provided in Standard Condition No. 4, will be made for "anticipated" customers later realized, for whom credit thus shall have been given in establishing the amount of the deposit. Should any applicant for water service for whom credit shall have been advanced fail to become a customer of the Water Company, the amount of the credit advanced in establishing the amount of the deposit shall be charged against the Applicant in computing the amount of refunds later due on account of new customers as provided in Standard Condition No. 4.

Standard Conditions

1. The Water Company agrees that, upon deposit with it of the sum designated, it will install the water main necessary to serve the streets listed as expeditiously as is consistent with the availability of labor and materials and the status of the Water Company main-laying program at the time the deposit is made. It is understood and agreed that the Water Company shall not be liable in damages to any person for failure to install said water main within any certain period of time, regardless of the nature of the damages claimed. Should a period of 180 days elapse after payment of said deposit without the starting of construction of said water main, the Water Company will, upon written demand from the Applicant, refund the entire amount of said deposit, and cancel this application and agreement.

2. It is understood that should the Water Company choose to install mains larger than necessary to furnish adequate water service for the abutting properties, the additional expense of such larger mains shall be borne by the Water Company.

3. The Applicant agrees that the above named water mains shall be and shall remain the property of the Water Company and that the company shall have the right to make any further extensions therefrom, and the Applicant shall not by reason of such further extensions be entitled to any payments in addition to those herein provided.

4. Except as otherwise provided, at the expiration of each of the first eight calendar years next following the year in which the installation shall be completed, the Water Company will refund to the Applicant a sum of money equal to six times the amount received by the Water Company for water service from each bona fide new customer connected to the main during the first 12 months such new customer shall have used such water service; provided, however, that if such new customer shall by reason of leaks, or abnormal or unusual use of water during such 12 months' period, consume an amount of water not normally consumed on corresponding premises, the amount of money to be refunded with respect to that consumer shall be six times the amount of water revenue which normally would be paid for water consumed during a 12 months' period on comparable premises or property. It is understood that only one such refund will be paid for each new customer.

5. No refund will be made by the Water Company for water used by any "anticipated" customer for whom credit shall have been allowed in establishing the amount of said deposit.

6. Any money which shall become payable to any applicant herein, as a refund under this agreement, and which is not claimed by such applicant or which the Water Company is unable to remit to such applicant because of lack of knowledge of the address or whereabouts of such applicant, shall be held by the Water Company until one year after the expiration of the period of time during which refunds may be paid under this agreement as herein provided, whether such period for the making of refunds terminates by the running of said eight-year refund period or by reason of refunds made. Upon the expiration of such one-year period, all such refund money then so held by the Water Company shall become and be the property of the said company.*

7. The Applicant agrees that all right of refund shall cease upon the expiration of the aforesaid one-year period following the end of the eight-year refund period, or following the time when the aggregate amount of refunds due shall equal the amount of the deposit paid by the Applicant under this agreement. It is understood that under no circumstances will the total amount of the refunds to be paid to the Applicant exceed the amount of the deposit made to the Water Company by the Applicant.

IN WITNESS WHEREOF, the Applicant and the Water Company have caused these presents to be executed this ....day of..................194....., in duplicate.

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* So far as the writer knows, this provision has not withstood the review of utility commissions. The opinion of attorneys is that it should be enforcible if it is included in the contract.

Problems in Cathodic Protection

By Frank E. Dolson

A paper presented on July 25, 1947, at the Annual Conference, San Francisco, by Frank E. Dolson, Dist. Engr., St. Louis County Water Co., University City, Mo., and Secretary, Correlating Committee on Cathodic Protection.

CORROSION has become a problem of increasing concern to those charged with the responsibility for installing underground metal structures. One of the reasons for our high standard of living is the underground network of pipes, cables and conduits that supplies many of our basic utility needs. In our accepted standard of living it is customary to take these utility services for granted, yet a recent survey indicates that approximately 210,000 miles of cast-iron pipe have been installed in public water supply systems to supply this need alone (1). In 1938 it was estimated that there were approximately 138,000 miles of gas distribution pipe, and about 65,000 miles of large-diameter natural gas transmission lines (2). Since then many thousands of miles of gas pipes have been constructed. Petroleum transportation by pipeline has, in recent years, become what might be termed a new industry. In transporting this valuable liquid from fields of production to points of usage enormous quantities of pipe have been used. The trend in the diameter of these lines is toward sizes familiar to all water works people.

Although there is no exact way to estimate the loss of metal due to corrosion in these underground structures, it is well known that the losses exist and at some time will show up in the depreciation account. The U.S. Bureau of Standards estimated the cost of pipeline replacement to be $200,000,000 per year (3). In view of our reckless use of metal and our rapidly diminishing supply of ore, it behooves industry to combat corrosion wherever possible. Good engineering also requires that corrosion be abated wherever it is economically feasible to do so.

In recent years corrosion has received considerable attention, since almost every industry has some problem in need of solution. All water works men are familiar with the products of corrosion. Many of them have been confronted with pipelines that have lost their carrying capacity because of internal corrosion, and most of them have had to replace pipes that have become unsound or perforated because of external corrosion.

Mechanism of Corrosion

The electrochemical theory of corrosion proposed by W. R. Whitney in 1903 associated the corrosion of metal with the flow of electricity. According to this concept, the metal at corroding (anodic) spots tends to go into solution as ferrous ions, while at the cathodic areas hydrogen ions are released as atoms. A stable condition is soon reached and corrosion ceases, if other influences do not interfere.

When two dissimilar metals are buried in a suitable electrolyte, an electric current is caused to flow. The more noble metal becomes the cathode, the less noble the anode. Zinc and iron buried in soil and connected together by an external wire would cause a current to flow. Through the soil the flow of current would be from zinc (cathode) to iron (anode) and through the external circuit from iron to zinc. This is similar to the flow of current in a common dry cell. In the conventional sense, current flows from the positive pole (carbon, anode) through the external circuit to the negative terminal (zinc, cathode) and within the electrolyte from the zinc to the carbon.

Likewise, two pieces of metal of the same composition in a non-homogeneous electrolyte will cause a flow of current. This is known as a concentration cell. Differential aeration is the most common cause of this type of cell action. When a metal pipe is buried in the soil parts of it become anodic while other parts become cathodic. Sometimes the cathodes are remote from the anodes and are linked by what have been termed long-line currents. For the most part the anodes and cathodes are adjacent, as evidenced by pitting immediately surrounded by cathodically protected areas. Those portions of a buried pipe that are well aerated will become cathodic, while those lacking oxygen will be anodic.

This condition is one frequently encountered in practice. The current leaving the anodic area carries metal particles with it. These particles, upon encountering oxygen as they move into the soil, will combine to form iron oxide, thus in effect preventing the diffusion of oxygen toward the metal. This results in further shielding the anode from oxygen and helps the cell action to continue.

It can readily be seen that the oxygen is an important factor in the corrosion of iron. Differential aeration of a pipe produces anodes and cathodes, and since they are bonded together by the pipe, a closed circuit results which allows a flow of current. Theoretically this causes metal to be dissipated at 20 lb. per amp. per year, assuming 100 per cent efficiency. Depolarization processes at the cathode and shielding effect at the anode allow the continuation of the cell action to the detriment of the metal at points where current flows into the earth.

Cathodic Protection

Cathodic protection has become a most handy tool for combating corrosion. Although recognized at a much earlier date, its use did not become widespread until the early thirties, when installations were made on gas and oil pipelines. A favorable change in the slope of the leak-time relationship curve and a corresponding decrease in maintenance cost soon resulted.

Cathodic protection consists in causing a current from an external source to flow from the soil to the corroding pipe. This current is superimposed on that resulting from the many local-action cells. A portion of it flows to the cathodes and a portion to the anodes. The amount flowing to each is a function of the resistance near the anode or cathode. When all of these local-action currents are suppressed by the current from the external circuit to such an extent that no current leaves the pipe at anodic areas, corrosion will stop. Increasing current beyond this value changes the soil-to-pipe potential, and hydrogen is released.

In practice cathodic protection is accomplished either by burying a mass of scrap metal (ground bed) and applying an external source of power from a rectifier, for example, or by the use of galvanic anodes, such as magnesium. The location of the ground bed and power requirement are determined by field measurements, as is the extent of the pipe protection. The positive terminal of the external power source is connected to the ground bed, while the negative terminal is connected to the pipe. Corrosion of the pipe is replaced by corrosion of the metal comprising the ground bed.

Cathodic protection is enjoying increasing popularity as an economical way of combating corrosion processes. A survey of three large companies revealed a total of 1,600 installations of all different types protecting about 3,400 miles of pipe. Well-coated, poorly coated and bare pipelines are being protected by rectifiers or by gas- or windmill-driven generators. Two of the companies report units with a maximum output of 150 amp., while the third has a 200-amp. installation in service. Some field data indicate that 69 miles of well-coated pipe could be protected with a current flow of only 2.5 amp. In many protected installations other structures would have been adversely affected had not proper corrective steps been taken. One operator estimated that about 10 per cent of his units were located in urban areas where problems of cathodic interference occurred. Even outside these urban areas, other underground facilities make caution necessary.

Cathodic Interference

One of the most important inter-industry problems derived from cathodic protection is cathodic interference. This is, and should be, a cause of concern to the operators of nearby structures. When a foreign structure becomes a part of the electrical network caused by the cathodic protection installation, a loss of metal occurs on the foreign pipe at those points where interference current is discharged into the earth for return to the protected pipe (4, 5).

Cathodic interference can be minimized by selecting the proper location for the ground bed. Field practice dictates that ground beds should be placed in low resistance soil, if practicable, and at the location where the best possible spread of protection is obtained. Frequently the location of the ground bed which is proper for the protected pipe is not the location which is proper for least interference with contiguous foreign lines. In a poorly designed installation, interference current in a foreign structure may be as much as 50 per cent of the total current.

If the optimum location for a ground bed is selected, interference can be reduced to 5 per cent or less of the total. Excessive interference current is undesirable to the owner who is installing protection, because it represents an increase in power cost for which no corresponding protection is obtained. The foreign line, if not properly drained, will, of course, suffer from electrolysis where the stray current discharges into the earth. This is analogous to the electrolysis caused by electric railways, although such problems are somewhat more complicated because the engineer has no control over the cause. Interference caused by cathodic protection offers more scope for remedial measures, because both the current output and location of the ground bed are subject to selection.

In order to solve interference problems effectively, it is necessary to understand the action of adjacent or remote anodes and cathodes on a conductor lying within their fields. Consider for a moment a point anode with current from an external source flowing into it and discharging into the earth. The potential of the anode is forced above that of the ground. If the earth were homogeneous and no other structures were in the field, equipotential lines surrounding the anode

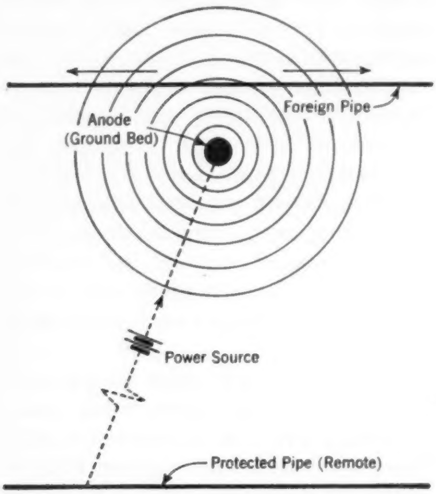

FIG. 1. Effect of Near-by Anode on Current Flow in Foreign Pipe

would form concentric circles with the potential gradient sloping from its highest value near the anode to smaller values as the distance from the anode increases. A current is caused to flow in any conducting structure crossing these equipotential lines, because such a structure is merely one of the many parallel electrical paths through the earth. The direction of flow would be from the anode toward the points of lower potential. Figure 1 illustrates this condition. At some location where the influence of the anode is exceeded by that of the cathode, the conductor would begin to discharge.

A cathode has a similar effect on the soil, but in the opposite direction. Its potential is forced below that of the soil in which it is located. The potential of the soil is also lowered, the point of lowest potential being nearest to the cathode. It becomes greater as the distance away from the cathode increases. Should the cathode be a pipeline and the anode be remote, the flow of current on a foreign line laid paral-

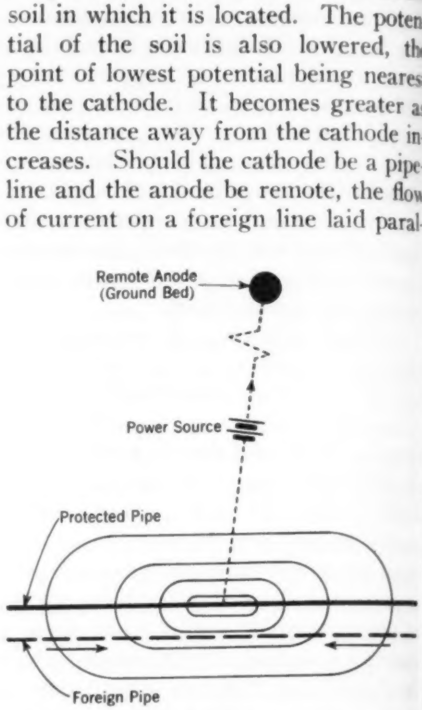

FIG. 2. Effect of Near-by Cathode on Current Flow in Foreign Pipe

lel to the cathode would be toward the cathode attachment (Fig. 2).

It is apparent that an anode raises the potential of the earth and a cathode lowers it. An anode, therefore, can be located so that its effect on a foreign structure is nearly balanced by that of the cathode. An exact balance is never obtainable because of the lack of symmetry between the anode and cathode. It is possible, however, to reduce interference current to a minimum and to cause it to flow in a direction where its disposal is easiest. Figure 3 illustrates these conditions.

With the anode at A, the combined effect of the anode and cathode is such that the current flow on the foreign line is away from the anode. When the anode is remotely located, as in position B, the current flow is toward the point of greatest difference of potential between the two structures. It will be observed that by changing the location of the anode it was possible to reverse the direction of current flow on the foreign pipe. At some location between A and B, the effect of the anode and cathode upon a foreign structure is almost equal, and interference current is at a minimum. As the solution of these problems is simplified when the current distribution is similar to that shown in B, it is desirable to locate the anode slightly beyond the balance point toward B. In field practice, if the geometric configuration of the involved structures is known, the best location for the ground bed is easily determined.

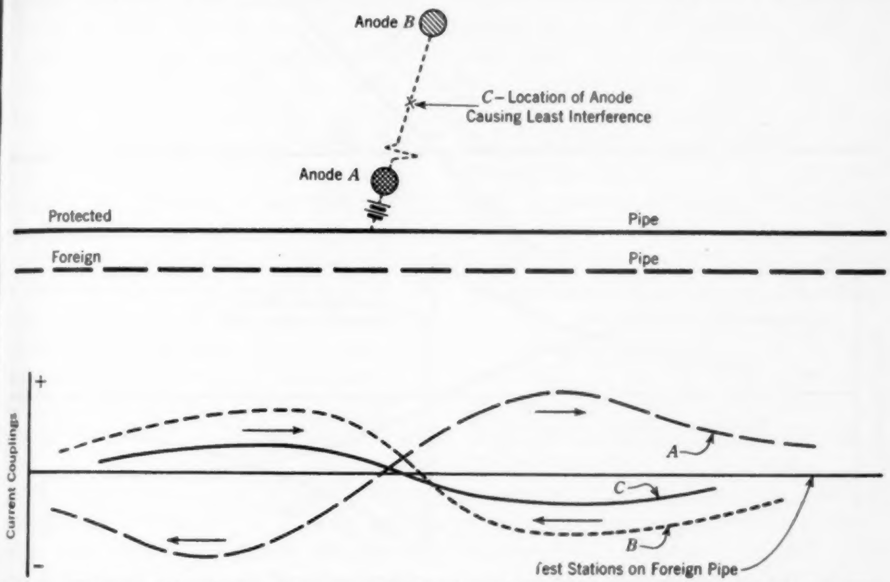

FIG. 3. Effect of Anode Location on Distribution of Interference Current in Foreign Pipe

In order to design a resistance bond that will properly drain interference current from a foreign structure to one under protection, it is necessary to make field measurements. Current measuring stations are established on the foreign line, and calibrated to read true line current. Terminals are also established to read pipe-to-soil and interstructure potential. With the bond opened, the distribution of anode current in the foreign line is measured as a ratio. For example, $\Delta I_x/\Delta I_A$ equals the current at station x per ampere of test current at the anode. As the increment of current observed at the terminal pair in question is the result of interrupting a known test current, other current that may be flowing is eliminated from the observations. When these readings are plotted against station numbers, the point can be determined at which the interference current is lost at the highest rate. If, by proper drainage, the

exposure at this point is corrected, all points of lesser exposure will be also.

In a like manner, the distribution of bond current in the foreign line is measured. A known test current is made to flow from one pipe to the other and then interrupted. Its effect, ΔI_x and ΔI_y, is measured at stations x and y. The ratio $\Delta I_x/\Delta I_B$ is the fraction of current appearing at sta-

$$\left(\frac{\Delta I_x}{\Delta I_A} - \frac{\Delta I_y}{\Delta I_A}\right) I_A = \left(\frac{\Delta I_y}{\Delta I_B} - \frac{\Delta I_x}{\Delta I_B}\right) I_B$$

in which ΔI_A is the increment of test current interrupted at A, ΔI_B is the increment of test current interrupted at B, I_A is the anode current and I_B is the bond current. The only unknown in this formula is I_B, because the value of the current couplings,

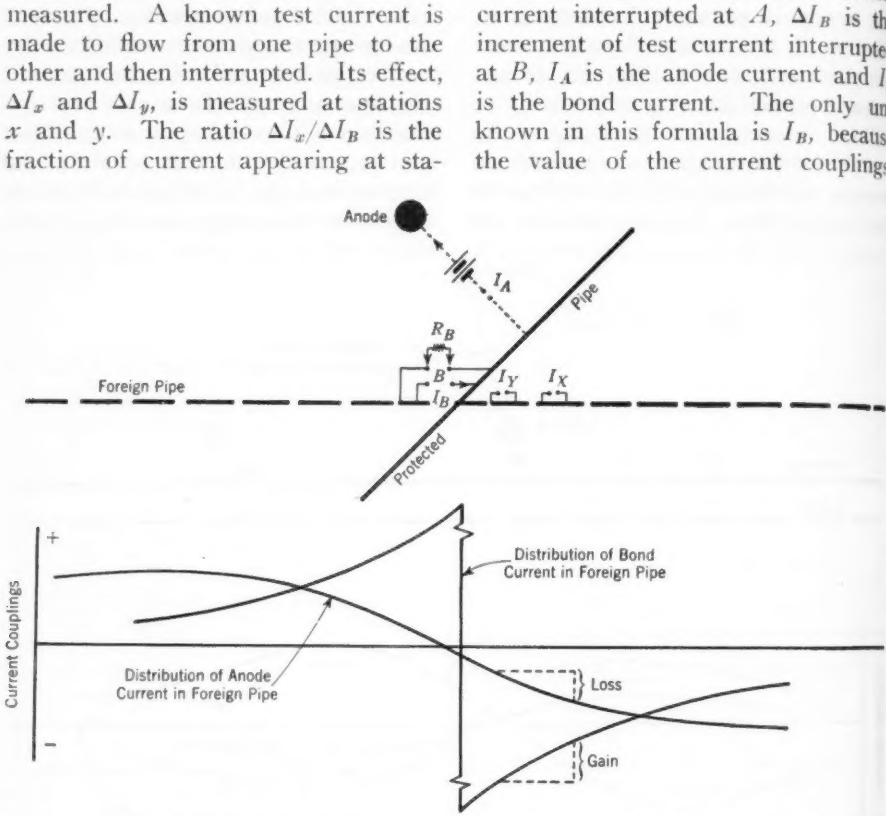

FIG. 4. Typical Interference Problem Showing Distribution of Anode and Bond Current in Foreign Pipe

tion x per ampere of test current at B. With this data in hand, and knowing what the rectifier requirements (I_A) are, it is a simple matter to calculate the bond current necessary to eliminate the interference exposure.

Figure 4 illustrates a simple crossing of two pipelines, one of which is cathodically protected, the other suffering from interference electrolysis. The bond current necessary to balance the loss of interference current between stations x and y can be calculated:

$\Delta I_x/\Delta I_A$, is measured and I_A is known. It is presumed that stations x and y have been located so that the maximum loss of interference current may be measured.

The bond resistance which will pass the required bond current can be obtained from the equation:

$$I_B = \frac{E_G + I_A R_{BA}}{R_{BB} + R_B}$$

in which I_B represents the bond current, E_G is the galvanic potential between the pipes, I_A is the anode cur-

rent, R_{BA} is the change in voltage at B per ampere of test current at A (mutual coupling resistance), R_{BB} is the internal resistance between the pipes measured by observing the change of voltage at B per ampere of test current at B and R_B is the bond resistance.

The correctness of the resistance which has been installed in the bond may be proved by observing the change in the pipe-to-soil potential when the anode current is turned on and off. In the region between stations x and y, the pipe-to-soil potential should remain unchanged. In all other parts of the line that are within the influence of the protection installation, the soil potential relative to the pipe should become more positive when the anode current is turned on.

Another method of eliminating interference current is by the use of insulating joints. If the anode has been properly located and is causing only minimum interference, a sufficient number of insulating joints, properly placed, can be used to prevent current flow on the foreign line. In underground piping systems in which pipes are joined together at frequent intervals with joints of varying conductivity, it is desirable to confine the anode current entirely to the protected pipe or to insist that the anode be placed so as to cause minimum interference. The crossing of steep potential gradients by a cast-iron pipe joined with either lead or sulfur cement compounds is hazardous and should be avoided.

Necessity for Co-operation

In order to remove these destructive interference currents, a certain amount of co-operation between managements is necessary. To demonstrate this need, a typical problem may be examined. Assume that the operators of one structure are not satisfied with the corrosion condition existing on their pipeline and have selected cathodic protection as the method to stop this destructive action. In making the installation, interference is caused on a foreign line, the owners of which are satisfied with the corrosion conditions existing on their line. It is generally recognized that the responsibility for mitigating the interference current lies with the one responsible for its existence. Some co-operation is required, however, from the owner of the foreign line. The location of the foreign line must be known. Permission must be obtained to establish test stations and make field measurements. If such measurements indicate a resistance bond is needed to drain the unwanted interference current properly, the owner of the foreign line must co-operate to the extent of allowing a drainage connection on his pipe.

Undoubtedly co-operation involves time, expense and trouble, but there is no reason to believe that these elements will not always be present in solving interference problems. The expense of making the survey and installing the corrective measures should, however, be assumed by the party making the installation. The cost to the owners of the foreign line would probably consist in having one of their engineers act as an observer while the field work was being done. This act of co-operation with its attendant expense is not unlike many others required of all utilities. It is also considerably cheaper to co-operate at the inception of the problem than to wait until failures occur, at which time the source of the breakdown must be ascertained before remedial measures can be effected.

Another interindustry problem is one of notification. In localities en-

joying the benefits of an active local electrolysis committee, notification procedure is simplified and usually involves only the filing of a letter of intent to the committee. All members of the group receive notification of the proposed work and those whose facilities may be damaged have the privilege of taking appropriate action. In other localities, in which there is no active local organization to clear such matters, the problem of locating affected structures and ascertaining ownership for the purpose of notification is often exceedingly difficult. Structures which do not cross and are not closely parallel to the protected pipe may suffer damage. A third crossing pipe may be the means by which the network is tied together. Sometimes the presence of a foreign line may remain unknown until failure is caused by interference current. Some means by which the operator contemplating protection is assisted in discharging his responsibility of notification would be desirable for all concerned. A national directory showing ownership of pipes, cables and other underground installations has been suggested.

Joint Installations

In practice, joint installations are one of the simplest interindustry problems. Each operator has the same objective: to prevent corrosion on his pipe. Sometimes the problem is solved by installing a solid bond between the structures and designing the protection system as if only a single structure existed. In general, joint installations are co-operative problems in which the interests of the parties involved are similar, and methods of prorating cost and other attendant problems are usually worked out satisfactorily.

Correlating Committee

A Correlating Committee on Cathodic Protection has been formed. The A.W.W.A. is a participating member along with ten other associations and industry groups. Its objective is to assist operators in solving these interindustry problems by the issuance of informative bulletins that can be published in the various journals for membership consumption, thus providing a broad basis for understanding cathodic protection problems.

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Discussion

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The author quoted the U.S. Bureau of Standards as indicating that pipeline replacements cost $200,000,000 a year. Such an amount, though small compared to the dollar investment in our vast underground network of pipes, cables and conduits, cannot be ignored as an incidental and necessary expense.

Regardless of the accuracy of the $200,000,000 figure, it can be assumed that the waste due to corrosion is a tremendous sum that might well be

saved for new construction of necessary water works improvements.

Volumes have been written about corrosion, and millions of dollars have been expended in developing corrosion-resistant materials. Each year some progress is made toward eliminating corrosion losses. Cathodic protection has now proved its merit, and the author has adequately described its use and the technicalities involved. When a new tool is introduced, a new scheme of living proposed or a new method of doing business adopted, however, certain obligations are thereby incurred. One of these is that no damage shall accrue to one's neighbor. This is in accord with the law of the land which provides for the protection of life and property.

One disturbing feature of cathodic protection, when installed to protect one set of underground structures, is that it can cause damage to adjacent structures. This is no reason for condemning the process, but it does impose an obligation on the user to protect adjacent structures and upon the owners of adjacent structures to inform the user, so that protective measures can be properly planned and carried out.

As a highly scientific process, cathodic protection may not be understood easily except by an electrical engineer. Its installation and operation, therefore, should be under the direction of trained personnel. Not all water works operators have personnel with such experience. At present engineers familiar with cathodic protection methods are practically all in the employ of the "long-line" operators. It is that group which is doing the pioneering and making the largest number of installations. Although they are the ones to carry the major load, they should not be asked to do it alone, particularly when "foreign lines" may be benefited rather than damaged.

Complete and effective co-operation is necessary. This involves notification of intention when new installations are to be made and location diagrams of adjacent structures or near-by pipelines, as well as many other matters which are problems to be handled only by experienced men. Furthermore, co-operation means the dissemination of new information as it is obtained, the determination of mutual benefits and the appraisal of any individual damages.

As each new installation of cathodic protection is made, new and complicated problems develop. Questions arise. Who pays whom for what service and how much? Who is responsible for damage if no preliminary investigations and reports have been made on buried structures?

The cross-country or long-line pipe companies have been cognizant of these problems and responsibilities. H. H. Anderson, Vice-President, Shell Pipe Line Corp., Houston, Tex., felt this obligation keenly. In an attempt to to meet it, he invited representatives of all interested national organizations to attend a meeting at St. Louis to discuss the problem. F. E. Dolson, the A.W.W.A. representative at that meeting, is to be highly complimented for the excellent report which he submitted. At the conference, the long-line operators, although desiring co-operation, at first held the view that it was the duty of operators of existing buried structures to notify the newcomers so that steps could be taken to bond and otherwise protect adjacent structures against artificially imposed corrosion. The stand now taken is that the obligation rests squarely on those who install cathodic protection.

Because of the imperative need of wholehearted, efficient and nation-wide

co-operation, this writer, in October 1946, proposed that a group of subordinate organizations supplement the work of the now activated Correlating Committee on Cathodic Protection. It is proposed to establish a complete and unified "chain of command" from the national committee down through an "area council," a "regional group," a "county board" and the "local committee" (see the appendix).

Such a plan, if adopted and developed logically, would achieve close local co-operation, provide for effective dissemination of new knowledge, create standard procedures of notification, insure up-to-date directories of the operators of underground structures and, finally, bring benefits which would accrue to all operators and result in the least individual cost for the maximum protection.

APPENDIX

Organizational Scheme for Cathodic Protection Committees

1. *Local Committee.* The local committee should be a relatively small local group confined within the geographical or political limits of a municipality. The street superintendent, city engineer or the chairman of the substructure committee might be the local head. He would have access to all files and plans of underground structures within the vicinity because of the issuance of necessary excavation permits. This basic committee would have active and correct directories of all operators of underground structures and an inventory of those structures. A newcomer in the field could thus quickly and inexpensively receive effective co-operation. This group should have at hand, or possibly in its employ, adequately trained personnel to control and perhaps install all cathodic protection instituted in the area. The local committee could, through close co-operation and working agreements, determine costs and benefits, differentiate between joint problems and problems of interference and arbitrate damage cases.

2. *County Board.* The county board would serve an entire county and include two or more local committees. In Los Angeles County, for example, it might embrace 584 separate agencies serving water to major gas companies, telephone and telegraph companies and many oil companies. This group would be the co-ordinator of the efforts of the local committees. It would be administrative only.

3. *Regional Group.* The regional group would embrace a state or geographical region. Its functions would be administrative, co-ordinating several county boards. It could maintain a directory of the heads of the various county boards within its jurisdiction.

4. *Area Council.* The area council would embrace three or four regional groups. Such a council might even serve the eleven western states. It would be within the province of the council to sponsor quarterly or yearly meetings for the presentation of technical papers and it would co-ordinate the work of regional groups.

5. *National Correlating Committee.* The National Correlating Committee on Cathodic Protection, which is already activated, would have to settle all the objections advanced at the meeting called by the committee chairman, H. H. Anderson, at St. Louis. There

should be a subcommittee for the primary purpose of developing factual information and disseminating it through bulletins to all agencies. The Correlating Committee would be the sponsoring agent of all the other groups and would function as the final board of arbitration in any disputes.

Possible Modifications

If the realization of the above plan were made the first objective of the correlating committee, the organization would proceed rapidly and successfully. Only minor modification of the four points already proposed would have to be made, possibly along these lines:

1. *Bulletins.* *a.* Authoritative technical information following the general outlines of the four bulletins presently proposed by the correlating committee. *b.* A quarterly news letter directed through the various sections of the organization, perhaps prepared so that the area council, the regional group, the county board and the local committee could each add a mimeographed page, thus forming a "chain letter" from the National Co-ordinator through all the sub-groups directly to members of the local committee.

2. *Notification Procedure and Directory.* The procedure for notification and the keeping of a directory should be entirely local, except for the issuance of authoritative information bulletins to standardize notification procedures and national policies. The burden of notification should be placed on the new agency in any locality. The local group, having a current directory, could make maps showing locations of underground structures. From the general organization directory, any new agency coming into the area could learn where accurate information may be obtained, thereby facilitating immediate co-ordination.

The national directory should include only the heads of the area council, the regional group and perhaps the county board. Such a relatively small directory could be kept current and be reasonably accurate. In this way the new operator in any territory could determine where to apply for local directories. The national directory as described would be for the particular benefit of the cross-country pipe companies. The national directory might be confined to indicating regional areas only, whereas regional groups could be consulted for the boundaries of the county board and local committees.

3. *Design.* Design is a local committee job, but the basic engineering should be cleared nationally through the authoritative information bulletin or the periodic news letters. Each local area would develop its own rules of procedure and engineering solutions based primarily on local geographic, topographic, geologic and structural conditions.

4. *Joint Problems.* The local group would govern under a charter from the Correlating Committee. Provisions would then follow for joint installations, payment and the like. Individual rights would be determined and provided for. Controversies which might develop could be arbitrated, if necessary, through the "higher courts," for example, the county board, regional group, area council and National Correlating Committee.

Calculation of the pH of Saturation of Tricalcium Phosphate

By Jerome Green and Joseph A. Holmes

A paper presented on July 24, 1947, at the Annual Conference, San Francisco, by Jerome Green, Chief Physical Chemist, and Joseph A. Holmes, Asst. Vice-Pres., National Aluminate Corp., Chicago.

EFFORTS in recent years to place water conditioning on a more exact and scientific basis have led to a closer examination of solubility relationships which involve relatively insoluble compounds occurring in natural and treated waters. Considerable attention has been given the utilization of information concerning the solubility of calcium carbonate (1–4), while the initial steps have recently been taken in the direction of a better understanding of the solubility relationships involving magnesium hydroxide, another common component of water-formed deposits (5).

The increasing use of molecularly dehydrated phosphates for calcium carbonate stabilization and corrosion inhibition and of orthophosphates in hot-process softening has made it desirable to obtain more information concerning the solubility of the calcium phosphates which are sometimes associated with phosphate treatment. Such information would be useful in at least two ways: it would enable one to recognize the conditions under which calcium phosphate precipitation can occur, thereby indicating the measures necessary to avoid such precipitation, and it would furnish a sounder basis for estimating the ultimate calcium reduction attainable by phosphate softening under given conditions.

Calcium Phosphate Precipitates

The starting point in the development of the relationships involved in the solubility of a slightly soluble compound is the physico-chemical relation known as the solubility product principle. One of the conditions implicit in the solubility product principle is that the composition of the solid phase concerned be definite and constant. Unfortunately, from the standpoint of the application of this principle to calcium phosphate solubility in natural and treated waters, this condition is not generally met. There have been a large number of statements, often contradictory, about the composition of the calcium phosphate solid phase existing in contact with aqueous solutions. Depending on the conditions of formation, such as the order of addition and relative excess of reagents, calcium phosphate precipitates of widely different chemical composition can apparently be obtained. Precisely such variation in conditions is likely to be encountered in water treatment. Calcium phosphate occurring in a softening process is ob-

viously formed under conditions considerably different from those existing in waters where orthophosphate ion is furnished by the reversion of a molecularly dehydrated phosphate.

It has been customary to assign the formulas of tricalcium phosphate, $Ca_3(PO_4)_2$, or hydroxyapatite, $Ca_{10}(OH)_2(PO_4)_6$, to calcium phosphate deposits, and although this procedure may be justified in some instances, it is likely that more often convenience rather than exact information has dictated such a course. The subject of the calcium phosphates was critically reviewed a few years ago, and the conclusion reached was (6):

> . . . between dicalcium phosphate and lime there exists, in the ternary system [CaO-P_2O_5-H_2O], a continuous series of solid solutions having an apatite lattice. It follows from this that tricalcium phosphate and hydroxyapatite do not exist in aqueous systems as unique, stoichiometric compounds.

Although tricalcium phosphate and hydroxyapatite are generally regarded as the least soluble of the calcium phosphates, it is possible that, because of differences in the rate at which equilibrium is attained, a calcium phosphate more soluble than tricalcium phosphate or hydroxyapatite may be precipitated from solution under such conditions that its solubility product is exceeded. Thus, some evidence has been obtained in the authors' laboratories for the existence of dicalcium phosphate in deposits formed from calcium-carbonate-stabilized waters containing relatively high concentrations of a molecularly dehydrated sodium phosphate.

Because of the uncertainty about the composition of the calcium phosphate solid phase, the quantitative application of the solubility product principle to solubility relationships of this substance is questionable. It appears probable, however, that the principle would be of qualitative significance and would serve as a guide for the experimental investigation of these relationships. With this end in view, an expression is derived in this paper for the solubility of tricalcium phosphate in terms of pH (called, for convenience, the pH of saturation of tricalcium phosphate), other readily determinable variables, and the physical constants involved. Values of the terms in this expression are tabulated in a manner which permits a rapid calculation of the pH of saturation, or any other variable involved, for a variety of conditions. The selection of tricalcium phosphate as the solid phase for these calculations was based on the fact that this compound is the least soluble of the calcium phosphates for which the necessary solubility data are available. The accumulation of experimental data may make it more desirable to formulate solubility relationships in terms of some other calcium phosphate.

Derivation of Expression for pH_s

The expression for the pH of saturation of tricalcium phosphate is derived as follows: the solubility product relation is

$$(Ca^{++})^3(PO_4^{---})^2 = K_s \ldots\ldots (1)$$

where the expression in parentheses equals activity, or effective concentration, and K_s equals the solubility product (more exactly, the activity product). The activity, or effective concentration, of PO_4^{---} is related to pH and the ionization constants of phosphoric acid, K_1, K_2 and K_3:

$$\frac{(H^+)(H_2PO_4^-)}{(H_3PO_4)} = K_1 \ldots\ldots\ldots (2)$$

$$\frac{(H^+)(HPO_4^{--})}{(H_2PO_4^-)} = K_2 \ldots\ldots\ldots (3)$$

$$\frac{(H^+)(PO_4^{---})}{(HPO_4^{--})} = K_3 \ldots\ldots\ldots (4)$$

Letting (Σ) equal the sum of the activities of phosphorus in its forms H_3PO_4, $H_2PO_4^-$, HPO_4^{--}, PO_4^{---}:

$$(\Sigma) = (H_3PO_4) + (H_2PO_4^-) + (HPO_4^{--}) + (PO_4^{---}) \ldots (5)$$

From Eq. 2, 3 and 4:

$$(H_3PO_4) = \frac{(H^+)^3(PO_4^{---})}{K_1K_2K_3} \ldots (6)$$

$$(H_2PO_4^-) = \frac{(H^+)^2(PO_4^{---})}{K_2K_3} \ldots (7)$$

$$(HPO_4^{--}) = \frac{(H^+)(PO_4^{---})}{K_3} \ldots (8)$$

Substituting in Eq. 5:

$$(\Sigma) = \frac{(H^+)^3(PO_4^{---})}{K_1K_2K_3} + \frac{(H^+)^2(PO_4^{---})}{K_2K_3} + \frac{(H^+)(PO_4^{---})}{K_3} + (PO_4^{---}) \ldots (9)$$

and solving for (PO_4^{---}):

$$(PO_4^{---}) = \frac{(\Sigma)K_1K_2K_3}{K_1K_2K_3 + (H^+)^3 + K_1(H^+)^2 + K_1K_2(H^+)} \ldots\ldots\ldots\ldots (10)$$

Substituting in Eq. 1:

$$(Ca^{++})^3\left[\frac{(\Sigma)K_1K_2K_3}{K_1K_2K_3 + (H^+)^3 + K_1(H^+)^2 + K_1K_2(H^+)}\right]^2 = K_s \ldots\ldots\ldots (11)$$

Rearranging, and writing in logarithmic notation:

$$2 \log \left[\frac{K_1K_2K_3}{K_1K_2K_3 + (H^+)^3 + K_1(H^+)^2 + K_1K_2(H^+)}\right] - \log K_s = - 3 \log (Ca^{++}) - 2 \log (\Sigma) \ldots (12)$$

The members on the left hand side of Eq. 12 are functions of temperature and, for convenience, are combined in a term called *pH-temperature factor*. The terms $- 3 \log (Ca^{++})$ and $- 2 \log (\Sigma)$ are called *calcium factor* and *phosphate factor*, respectively.

The final expression becomes:

pH-Temperature Factor
= Calcium Factor
+ Phosphate Factor . . (13)

Selection of Physical Constants

The pH-temperature factor involves the ionization constants of phosphoric acid and the solubility product of tricalcium phosphate. The first and second ionization constants of phosphoric acid have been accurately measured up to 50 and 60° C., respectively, but there is considerable disagreement among the values reported for the third ionization constant. Data for this latter constant, moreover, are confined to a relatively narrow temperature range. The values of the ionization constants used in the calculations in this paper have been critically selected from the literature and are given in Table 1.

A wide variety of values have been assigned to the apparent solubility product of tricalcium phosphate, ranging from 10^{-25} to 10^{-31} (7, 8). Because of the variable composition of calcium

phosphate precipitates, such disagreement is understandable. The selection of a value for this constant, however, is rendered very difficult. The situation is further complicated by the fact that measurements have been confined to a limited range of pH, usually to one temperature, and to solutions in which the ionic strength (that is, the content of dissolved solids) was relatively high.

A recent paper by Kuyper (9) presents solubility data on calcium phosphate obtained by approaching equilibrium from both directions, and his results are in reasonable agreement with those of other investigators. His data have been recalculated on the basis of the ionization constants of phosphoric acid selected here and corrected for ionic strength by the relations given by Sendroy and Hastings (8, 10). On this basis, the value for the solubility product of tricalcium phosphate is taken as 5×10^{-30} at 38°C. No experimental data are available on the effect of temperature on K_s.

TABLE 1

Ionization Constants of Phosphoric Acid Used in Calculations

Temp. °C.	$-\log K_1$*	$-\log K_2$†	$-\log K_3$‡
10	2.068	7.2537	12.56
20	2.100	7.2130	12.41
30	2.145	7.1891	12.26
40	2.197	7.1809	12.13
50	2.260	7.1831	12.00
60	2.327	7.1944	11.88
70	2.397	7.214	11.77
80	2.469	7.238	11.67
90	2.539	7.270	11.57
100	2.606	7.307	11.48

* From the smoothed data in Ref. 11. Values above 50°C. extrapolated.

† From the data in Ref. 12. Values above 60°C. extrapolated.

‡ From the smoothed data in Ref. 13. Values above 30° and below 20°C. extrapolated.

It would be desirable to have some independent method of checking the value of the solubility product selected. Thermodynamics furnishes such a means, but when recourse is had to this type of calculation it is found that the uncertainties in some of the thermochemical data reduce the results obtained to only qualitative significance. Such a calculation gives a value of 10^{-43} for K_s near room temperature and indicates that this value decreases slightly with increasing temperature.

TABLE 2

Calcium Factor for Calculation of pH_s of Tricalcium Phosphate

Calcium *ppm. as $CaCO_3$*	Calcium Factor	Calcium *ppm. as $CaCO_3$*	Calcium Factor
1	15.00	120	8.75
2	14.10	140	8.55
4	13.19	160	8.38
6	12.66	180	8.22
8	12.28	200	8.08
10	11.99	250	7.79
12	11.75	300	7.56
14	11.55	350	7.36
16	11.37	400	7.18
18	11.22	500	6.89
20	11.08	600	6.66
30	10.55	800	6.28
40	10.18	1000	5.99
50	9.89	1200	5.75
60	9.65	1400	5.55
80	9.28	1600	5.38
100	8.99	1800	5.23

The calcium factor and the phosphate factor involve the analytical determination of calcium and of total orthophosphate, respectively. As such analyses determine concentrations rather than activities, Eq. 13 should include a term to take this usually small difference into account. Because of the uncertainty in the value for K_s, however, such a refinement would appear to be unwarranted.

Method of Calculating pH_s

Tables 2, 3 and 4 contain values of the terms used to calculate the pH of saturation of tricalcium phosphate. The manner in which this is done can best be demonstrated by an illustration. Assume that a water has the following characteristics: calcium, 100 ppm. as $CaCO_3$; total orthophosphate, 10 ppm. as PO_4; temperature, 20°C. From Table 2 one obtains the calcium factor, which is found to be 8.99. The phosphate factor is obtained from

TABLE 3

Phosphate Factor for Calculation of pH_s of Tricalcium Phosphate

Orthophosphate *ppm. as PO_4*	Phosphate Factor	Orthophosphate *ppm. as PO_4*	Phosphate Factor
1	9.96	30	7.00
2	9.35	35	6.87
3	9.00	40	6.75
4	8.75	45	6.65
5	8.56	50	6.56
6	8.40	55	6.48
7	8.27	60	6.40
8	8.15	65	6.33
9	8.05	70	6.27
10	7.96	80	6.15
12	7.79	90	6.05
15	7.60	100	5.96
20	7.35	110	5.87
25	7.16	120	5.80

Table 3. For the condition given it is 7.96. These two values are added: $8.99 + 7.96 = 16.95$. In Table 4, under the column headed "20°C.," this sum is found, corresponding to a pH of 6.8. This is the pH of saturation of tricalcium phosphate for the conditions specified. If the pH of the water is above this value, tricalcium phosphate will tend to precipitate; if the pH is less than this value, tricalcium phosphate will tend to dissolve. It is obvious that given any three of the variables—calcium, orthophosphate, pH or temperature—the fourth can be found by the use of Tables 2, 3 and 4.

Application to Practical Problems

The use of molecularly dehydrated phosphates for calcium carbonate stabilization or corrosion inhibition is occasionally accompanied by the formation of calcium phosphate deposits which may interfere with the operation of equipment. The reaction of the molecularly dehydrated phosphates with water to form orthophosphate is the underlying cause for conditions leading to the formation of such deposits. The pH of saturation of tricalcium phosphate for these conditions can be calculated from a knowledge of the orthophosphate concentration which would result from complete reversion of the molecularly dehydrated phosphate, the calcium hardness and the temperature of the water. If the actual pH of the water is kept below this value, the precipitation of tricalcium phosphate theoretically should be prevented.

In hot phosphate softening it has been found by experience that in order to obtain substantially zero calcium hardness it is necessary to maintain a pH of 10.3 to 10.5 (measured at room temperature) in the presence of approximately 5 ppm. of orthophosphate, expressed as PO_4. If one assumes that the actual pH of the water at the reaction temperature, 210°F., is 9.0, it is calculated that a calcium concentration of 0.5 ppm., expressed as calcium carbonate, should prevail under these conditions.

Discrepancies may arise in the application of these calculations to practical problems. These may be due to one or more of several factors, disregarding errors introduced by uncertainties in the values of the physical

TABLE 4

pH-Temperature Factor for Calculation of pH$_s$ of Tricalcium Phosphate

pH-Temperature Factor

pH	°C.—10 °F.—50	20 68	30 86	40 104	50 122	60 140	70 158	80 176	90 194	100 212
6.0	13.64	14.00	14.32	14.64	14.86	15.04	15.30	15.42	15.58	15.68
6.1	14.02	14.38	14.69	15.02	15.44	15.56	15.69	15.81	16.02	16.04
6.2	14.40	14.76	15.07	15.38	15.90	16.04	16.05	16.20	16.46	16.42
6.3	14.78	15.13	15.45	15.74	16.30	16.46	16.44	16.57	16.89	16.81
6.4	15.14	15.51	15.82	16.14	16.68	16.84	16.81	16.94	17.32	17.19
6.5	15.52	15.87	16.18	16.50	17.04	17.20	17.18	17.32	17.73	17.59
6.6	15.90	16.24	16.53	16.88	17.38	17.56	17.54	17.70	18.13	17.94
6.7	16.24	16.61	16.88	17.24	17.70	17.88	17.91	18.06	18.50	18.30
6.8	16.58	16.95	17.22	17.60	18.00	18.18	18.25	18.40	18.87	18.68
6.9	16.94	17.29	17.57	17.92	18.31	18.49	18.60	18.73	19.20	19.02
7.0	17.30	17.61	17.92	18.24	18.59	18.78	18.92	19.06	19.52	19.38
7.1	17.62	17.92	18.25	18.56	18.88	19.08	19.25	19.40	19.83	19.70
7.2	17.94	18.23	18.57	18.86	19.18	19.36	19.57	19.70	20.12	20.02
7.3	18.24	18.53	18.86	19.14	19.44	19.66	19.87	20.00	20.39	20.34
7.4	18.54	18.81	19.13	19.42	19.72	19.94	20.16	20.30	20.65	20.64
7.5	18.83	19.08	19.40	19.70	19.96	20.20	20.44	20.56	20.90	20.93
7.6	19.10	19.35	19.66	19.96	20.22	20.46	20.71	20.84	21.14	21.20
7.7	19.38	19.60	19.92	20.20	20.46	20.70	20.96	21.10	21.36	21.47
7.8	19.62	19.84	20.17	20.44	20.69	20.94	21.20	21.34	21.59	21.72
7.9	19.86	20.08	20.40	20.68	20.92	21.18	21.43	21.58	21.82	21.96
8.0	20.10	20.32	20.64	20.92	21.16	21.40	21.67	21.80	22.04	22.20
8.1	20.32	20.54	20.86	21.14	21.37	21.64	21.89	22.03	22.26	22.44
8.2	20.54	20.76	21.08	21.36	21.58	21.86	22.12	22.24	22.47	22.66
8.3	20.76	20.98	21.29	21.58	21.81	22.06	22.33	22.46	22.69	22.88
8.4	20.97	21.19	21.50	21.78	22.02	22.28	22.54	22.68	22.90	23.10
8.5	21.18	21.41	21.72	22.00	22.23	22.50	22.75	22.90	23.11	23.32
8.6	21.38	21.62	21.94	22.22	22.44	22.70	22.96	23.10	23.31	23.52
8.7	21.60	21.83	22.15	22.42	22.66	22.90	23.17	23.31	23.52	23.72
8.8	21.80	22.04	22.36	22.62	22.86	23.10	23.36	23.51	23.73	23.94
8.9	22.00	22.25	22.56	22.83	23.08	23.30	23.57	23.72	23.93	24.15
9.0	22.20	22.46	22.76	23.02	23.28	23.52	23.76	23.93	24.13	24.36
9.1	22.43	22.66	22.96	23.26	23.48	23.71	23.97	24.12	24.35	24.56
9.2	22.64	22.86	23.17	23.46	23.69	23.92	24.17	24.32	24.54	24.76
9.3	22.84	23.06	23.37	23.66	23.90	24.12	24.36	24.53	24.74	24.97
9.4	23.04	23.27	23.57	23.86	24.10	24.32	24.56	24.74	24.93	25.18
9.5	23.24	23.47	23.77	24.06	24.30	24.54	24.75	24.93	25.13	25.38
9.6	23.45	23.67	23.97	24.26	24.51	24.74	24.95	25.12	25.32	25.58
9.7	23.65	23.87	24.17	24.45	24.71	24.94	25.14	25.32	25.52	25.78
9.8	23.86	24.07	24.37	24.65	24.91	25.14	25.33	25.52	25.71	25.98
9.9	24.06	24.27	24.56	24.85	25.10	25.34	25.52	25.71	25.91	26.18
10.0	24.26	24.46	24.76	25.04	25.30	25.53	25.70	25.91	26.09	26.37
10.1	24.45	24.66	24.96	25.23	25.50	25.73	25.89	26.10	26.28	26.57
10.2	24.65	24.86	25.14	25.42	25.70	25.92	26.07	26.29	26.47	26.76
10.3	24.84	25.05	25.35	25.62	25.89	26.12	26.25	26.48	26.66	26.94
10.4	25.03	25.24	25.54	25.82	26.09	26.32	26.44	26.66	26.85	27.15
10.5	25.22	25.44	25.73	26.01	26.28	26.50	26.62	26.85	27.03	27.35
10.6	25.42	25.64	25.93	26.21	26.46	26.69	26.80	27.04	27.23	27.55
10.7	25.62	25.84	26.12	26.40	26.64	26.88	26.98	27.23	27.41	27.74
10.8	25.82	26.03	26.32	26.59	26.83	27.06	27.16	27.42	27.60	27.94
10.9	26.00	26.23	26.51	26.78	27.01	27.24	27.34	27.61	27.79	28.14
11.0	26.20	26.43	26.70	26.98	27.19	27.44	27.51	27.80	27.96	28.35

constants used in the calculations. It should be realized that these calculations are based on equilibrium considerations and do not take into account such factors as the rate of attainment of equilibrium and the physical characteristics of the solid phase. Moreover, the calculations apply to the particular state under consideration. Measurements of pH made at temperatures differing widely from that in question may therefore be misleading. Finally, it should be emphasized that the solid phase has been assumed to be tricalcium phosphate, a condition which may not be encountered in practice.

A considerable amount of experimental work must be done before the solubility relationships of calcium phosphates actually encountered in water treatment can be established with certainty. This is especially true because of the variable composition of such phosphates, as has already been indicated. It is hoped, however, that the calculations which have been presented will prove useful in serving as a guide in the experimental aspects of the problem.

Acknowledgment

The authors wish to thank L. C. Bischmann for his assistance in the calculations.

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Radio Service in Water Systems

By Adolph Damiano

A paper presented on July 25, 1947, at the Annual Conference, San Francisco; prepared by Adolph Damiano, Prin. Asst. Engr., Hackensack Water Co., Weehawken, N.J., and read by B. A. Currie, Dept. of Water and Power, Los Angeles.

THROUGHOUT the ages, man has continually sought newer, faster and better means of communication. As a result of his ingenuity, he has discovered and perfected methods of transmitting messages over great distances at ever-increasing speed.

History of Communications

Let us review briefly the chronological progress of man's efforts to develop an adequate system or instrumentality of communication. The horse, of course, has served for many centuries as a means of swift conveyance; primitive societies adopted sound signals as a method of relaying messages from place to place; ancient civilizations used smoke by day and fire by night for both short- and long-distance transmission. Later, crude devices were set up to be seen from afar; by altering the positions of one or more of the several objects placed on them, and by using a pre-arranged code, a limited number of messages could be transmitted. The first system of aerial or optical telegraphy, discovered in 1684, was followed by the movable-arm semaphore telegraph on top of high signal towers. The invention and development of the electric telegraph first applied the medium of electricity to transmission, and the telephone was successfully introduced by Alexander Graham Bell in 1876 as a remarkable improvement over previous methods of communication. In 1897 the wireless telegraph was patented by William Marconi; and, finally, through the persistence and wisdom of the inventor, the scientist and the engineer, the electronic or radio means of communication—a wonderfully efficient system of transmission—was developed.

Enormous strides, therefore, have been made through the centuries in the transmission of signals and messages. Today radio accords us the most modern medium of rapid and satisfactory communication.

Use in Water Systems

There should be little doubt that this most recent discovery can and will serve as a powerful and almost indispensable operating tool. The water works industry must immediately recognize its value in the improvement of operation and maintenance procedure and practice. The industry must awaken from its habitual lethargy and discard its ingrained complacency toward the introduction and acceptance of this new labor- and time-saving device, this new type of supervision, this operational aid. Serving the wel-

fare of the general public, water works men must be ever receptive to changing philosophies, particularly as they affect the improvement of service to, and relationship with, the people in their communities.

The use of radio communication will expedite the dispatching of inspection and repair crews in situations necessitating quick action to prevent damage to life and property, waste of water, and interruption of domestic, industrial, public and fire service. Such a medium of transmission will enable the superintendent or manager of the water department to direct, personally or through his supervisors or foremen, the work required in all types of emergencies.

The policing of the watersheds of large water utilities may be more efficiently conducted by patrol cars equipped with radio receivers and transmitters. Accidents, fires and trespassing can be investigated more promptly and steps to rectify the situations can be taken immediately.

Inspection, either on foot or in a car, of long trunk mains and aqueducts may be accelerated if the inspector has a walkie-talkie or mobile radio to report the condition or trouble on the spot to the repair superintendent. Time can thus be saved and damage and waste accordingly kept to a minimum.

Reconditioning of water pipes may be more efficaciously accomplished if radio facilities are available. Operation of the supply gate to obtain a constant, predetermined rate of flow of water required for cleaning may thus be controlled. The progress of the cleaning tool can be followed and reported to the supervisor in charge of the work.

Trunk main pitometer tests to determine leakage or pipe coefficients may be facilitated by the use of radio if synchronization of readings is a prerequisite.

Walkie-talkies and handie-talkies will certainly find their place not only in construction work but also in the operation of such installations as pumping stations, filtration, sedimentation and coagulating basins—wherever wire communication is not feasible or practicable.

Radio contact with the office, shop or yard may be maintained by field crews during night hours to receive necessary instructions when telephones are not readily accessible.

Technical Adaptation

A more technical adaptation of the facilities of radio to the water works industry is made possible by the availability of microwave channels on the radio spectrum. Equipment utilizing these frequencies for telemetering, supervisory indications and remote control can be manufactured. Continuous records of water tank levels, river level gagings and reservoir depths may be transmitted to any location. Operation of sluice gates on dams and large-size valves on trunk mains and aqueducts can be effected by means of radio equipment. Remote control of isolated pumping units may be accomplished in this manner.

Telemetering provides a fundamental means for centralized control by furnishing a method of collecting and transmitting information to a centralized location. Such a medium of supervisory control becomes essential in the larger water works system in order to analyze major emergencies, interruptions or breakdowns.

The above functions have been provided for in the past through the use of wire circuits. It is necessary that

these indications and control operations be available and that they be transmitted reliably during periods of adverse weather conditions which may cause a disruption in the operation of a power system. Such disturbances may interrupt the wire communication service at the very times that it is most urgently needed.

These are a few of the many uses to which radio communication in the water works industry may be applied advantageously. Space does not permit detailed description and elaboration.

Responsibility to Public

The author feels confident that the water works industry recognizes its duty to the public. Its members are sincere and earnest in their determination to deliver a safe and potable water supply in sufficient quantities and at adequate pressures to meet not only normal but also emergency requirements. The public, unfortunately, generally regards the water supply system with much indifference. People do not realize their full dependence on their water supply until the service is interrupted. Then their reaction changes from apathy to consternation and criticism. In order to minimize the duration of these periods of emergency and to be able to employ prompt and effective means of correcting the situation, protecting the rest of the system and preventing unsanitary conditions, quick, reliable and accurate methods of communication must be adopted. The use of a mobile radio system, therefore, will most certainly achieve the purpose of rendering better service to the public.

Some private and municipal water departments have already availed themselves of mobile radio units, and others which up to now have given consideration to the establishment of such communication systems will undoubtedly decide to proceed with their plans in view of the recent Federal Communications Commission orders and notices on radio communications for power utilities, which will be discussed in this paper.

Utility Radio Service

In his capacity of adviser to the Association Committee on Radio Facilities for Water Works, the author has served as one of the A.W.W.A. representatives on Committee 4, Panel 13, of the Radio Technical Planning Board. This board was organized in 1943 as a result of a proposal by the Federal Communications Commission to the Radio Manufacturers Association and the Institute of Radio Engineers. The purpose of the board is to assist the FCC in postwar planning of frequency allocations and system standards for the radio services. The Radio Technical Planning Board is composed of a main board, an administrative committee, and thirteen panels dealing with many phases of electronic communication. Panel 13 includes nine committees under the general heading of Portable, Mobile and Emergency Services. Committee 4, Power Utilities, comprises representatives of electric, gas, water and steam companies of all classes. For several years, this committee has been engaged in correlating and crystallizing the frequency needs of the various industries represented and presenting these radio channel requirements intelligently and firmly before the FCC. Furthermore, this group has co-operated with the staff of the FCC in the formulation of satisfactory rules and regulations for the utility field. The

committee's negotiations with the FCC have been well conducted, and its accomplishments are impressive.

As a result of the diligent work of Committee 4 and the skillful presentation of its case to the FCC, a new "Utility Radio Service" was established by the commission and a new Part 17 of the Rules and Regulations governing its operations was made effective in September 1946. The Utility Radio Service now includes three classes of stations: power utilities, transit utilities and petroleum pipelines. Under this service the power utilities will share their frequency assignments with petroleum pipelines and "other industries requiring similar radio service." Steps have been taken by Committee 4 to have the FCC remove petroleum pipelines and "other industries" from this category.

An extract of the new Part 17 of the Rules and Regulations Governing Utility Radio Service has been published in an earlier issue of the JOURNAL (1).*

Power utilities which now have FCC licenses as special emergency stations may request a change of classification of their station to the new Utility Radio Service.

Part 17, although relaxing the use of mobile radio, does not permit unlimited freedom. Operation of radio was previously restricted to emergency communications only. The new rules grant a much wider latitude and will make it possible for utilities to render better service. Necessary dispatching in connection with the operation and distribution of a water supply is allowable, but routine conversations relating to functions which can be handled as efficiently over other means of communication are not permissible. Indiscriminate use of radio will be regarded significantly by the FCC in its probable future consideration of reallocation of frequencies on the basis of a higher priority for emergency services. Utilities are now considered an emergency classification, a designation which the industry should seriously desire to retain.

Frequency Allocations

After several years of negotiations with the various services, the FCC, on March 21, 1947, issued Public Notice 3529 covering Frequency Service Allocations to the Non-government Fixed and Mobile Services in the 30–40 Mc. band, effective April 1, 1947. Accordingly, all services for which channels have been provided in this band will be required to shift, no later than July 1, 1950, to frequencies in line with this plan.

Power, petroleum pipeline and other industries have been provided with two blocks of frequencies in the 30–40 Mc. band: 33.18, 33.22, 33.26, 33.30, 33.34, 33.38 (6 channels); and 37.46, 37.50, 37.54, 37.58, 37.62, 37.66, 37.70, 37.74, 37.78, 37.82, 37.86 (11 channels).

The FCC has suggested that Panel 13 of the Radio Technical Planning Board set up a committee to review the problem of conversion from the present interspersed service allocation plan to the block plan set forth in Public Notice 3529. The purpose of this study is to present recommendations for the transition in order that the change may be completed not later than July 1, 1950, as stated, in an

* A copy of the complete new Part 17 may be obtained by writing to the Secretary, Federal Communications Commission, Washington 25, D.C.

orderly and equitable manner. The findings of this committee will be made available as soon as they are released.

On July 19, 1946, the FCC issued Public Notice 95684 announcing the service allocations of specific frequencies to the Non-government Fixed and Mobile Services in the 72–76 Mc. band.

Power, petroleum pipelines and other industries have been assigned the following channels in two blocks: 75.42, 75.46, 75.50 (3 channels) and 75.58, 75.62, 75.66 (3 channels).

The FCC also issued on March 21, 1947, Public Notice 3544, Frequency Service Allocations to the Non-governmment Fixed and Mobile Services in the band 152–162 Mc., effective April 20, 1947. Power, petroleum pipelines and other industries have been assigned two blocks of frequencies in the 152–162 Mc. band: 153.59, 153.65, 153.71 (3 channels) and 158.01, 158.07, 158.13, 158.19, 158.25 (5 channels).

Field Tests

In order to determine the propagation characteristics for mobile service in the 30–40 Mc., 72–76 Mc. and 152–162 Mc. regions in the radio spectrum, the West Penn Power Co. in Pittsburgh, Pa., in conjunction with mobile radio equipment manufacturers and the FCC staff, conducted field tests this past spring in southwest Pennsylvania. This area includes both mountainous and rolling country. It is hoped that the results of these tests will soon be made available. In general, the higher frequencies are desirable in urban areas, because those frequencies are least congested. Very likely the FCC will require their use in urban districts.

Types of Radio Service

The three methods of securing radio service available to an applicant at present are (1) on a subscription basis from a common carrier, (2) under an ownership-sharing or facilities-rental agreement and (3) as the owner of an independent system. The communication companies during the past several years have made a determined effort to establish their own mobile services. Two types of service are being offered by telephone companies, under both of which they will furnish, install and maintain all the radio equipment required. The common-carrier type makes each channel a party line serving numerous subscribers. Such a system is operated on a common-carrier channel, and the communication company is the licensee. This type of service is dependent upon telephone circuits connected to remote receivers and is reliable only as long as these wired circuits are in operation. It provides no control of talk-back priority and thus it subordinates the water works user to the least essential subscriber on the channel. Furthermore, such a service could not cover the bulk of the utility territory outside of the metropolitan areas of the country. The common-carrier service, therefore, would not meet the needs of the water works industry, because emergencies occur without warning and the channels must be instantly available. The second type is a completely independent system furnished on a rental basis. It operates on a "power, petroleum pipelines and other industries" channel, and the subscriber is the licensee. This latter type renders a service fully equivalent to an independently owned system and the

preference between rental and ownership depends solely upon the economics of the specific choice. Nevertheless, the communicating companies are exerting every effort to control independent channels. The author urges the occupancy of the channels allocated to the water works industry to prevent them from being given to other services. It is predicted that there will be a heavy increase in the demands for radio service. This growth will make the allocated portion of the spectrum inadequate to satisfy the demand.

Regional Radio Groups

Committee 4 is now sponsoring and encouraging the formation of regional utility radio co-ordinating groups, associations or committees throughout the country. The organization of such regional bodies has been precipitated primarily because of the need for a national frequency-assignment pattern and because of the necessity of developing and promulgating good engineering and operating practices. Subcommittee 2 of Committee 4 has worked out a general plan for the formation and operation of such regional groups. A digest of this plan will soon be published for the benefit of those utilities which may be interested in forming new groups or joining existing ones.

Certain sections of the country have already been organized into regional groups. The rest of the United States has been tentatively divided into areas where such committees may effectively be established. The appendix to this article contains a list of these regions, including the names and addresses of the persons designated to receive inquiries or correspondence in their respective areas. It is hoped that the members of the A.W.W.A. will respond generously to the summons for representatives of the water works industry to attend meetings of the regional group covering their states. The interested and co-operative spirit that has always made the water works industry progress should be exhibited in these sessions. Water works men must offer dynamic participation in the activities of these regional groups, for they have a heavy responsibility for the success of this project. The author feels quite confident that they will be ready and eager to serve on these committees, and to stimulate the interest of their fellow-workers in this enterprise.

National Frequency Assignment

Another assignment completed by Subcommittee 2 of Committee 4 was the preparation of "A National Assignment Plan for Power, Petroleum Pipelines, and Other Industries, Frequencies." This plan constitutes a basic pattern for use as a guide in selecting the most suitable frequency or frequencies for any mobile radio system which is to operate on one or more of the frequencies allocated to power utilities, petroleum pipelines, and other industries. It will aid the various regional groups in developing a satisfactory schedule of frequency allocations for reassignment to present users. Its application to new systems will facilitate the co-ordination and development of frequency distribution with a minimum of interference between users.

User's Guide

A "User's Guide" which will serve as a manual for the Power Utilities Group is now in preparation. This material will offer suitable information about proper engineering and regula-

tory procedures for the guidance of prospective users.

Conclusion

Water works men have been reluctant to grasp and utilize the possibilities of radio in promoting service to the public. The advancement of this science, however, has opened a new vista, and the time for action is at hand. The cost of installing and operating such a system will quickly pay for itself in organizational efficiency. From the standpoint of improved public relations, the field is unlimited and the opportunities are unsurpassed. Radio comes as a challenge to the executives and managers of the water works industry who desire to improve their service to the public and their relationship to the community.

Reference

1. Federal Communications Commission: Rules Governing Stations in the Utility Radio Service. Jour. A.W.W.A., **38**: 1398 (1946).

APPENDIX

Regional Radio Groups

1. Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island:

R. W. Lewis
Boston Edison Co.
39 Boylston St.
Boston, Mass.

2. New York, New Jersey, Eastern Pennsylvania, Maryland, Delaware and District of Columbia:

G. H. Underhill
Central Hudson Gas & Elec. Co.
South Road
Poughkeepsie, N.Y.

3. Wisconsin, Michigan, Illinois, Indiana, Ohio, West Virginia, Kentucky and Western Pennsylvania:

J. G. McKinley
West Penn Power Co.
14 Wood St.
Pittsburgh 30, Pa.

4. North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, Missouri, Oklahoma and Arkansas:

H. W. Chew
Empire District Elec. Co.
Joplin, Mo.

5. California, Nevada, Arizona, Wyoming, Colorado and New Mexico:

C. T. Malloy
Southern California Edison Co.
601 West 5th St.
Los Angeles 53, Calif.

6. Washington, Oregon, Idaho, Montana and Utah:

W. A. Leidigh, Jr.
Portland General Elec. Co.
621 South West Adler St.
Portland, Ore.

7. Texas:

Paul Taylor
Central Power & Light Co.
120 Chaparall St.
Corpus Christi, Tex.

8. Virginia, North Carolina, South Carolina, Tennessee, Florida, Georgia, Alabama, Mississippi and Louisiana:

T. G. Humphreys, Jr.
Birmingham Gas Co.
1918–20 North First Ave.
Birmingham, Ala.

Discussion

W. C. Morse

Supt., Water Dept., Seattle, Wash.

When Marconi first discovered how to utilize the hertzian wave commercially, he had no more idea of what his discovery would develop into than we have today of what the ultimate use of atomic forces will be. Marconi's work, although so important that it will for all time occupy a place in history, has been improved upon and expanded so that now it is like a great oak tree compared to an acorn. What the future holds in store for the development of the principles first put to practical use by Marconi is beyond the imagination. The horizon is so broad, yet so obscure, that no one can possibly see beyond it, but it is certain that advances will continue at a rapid pace, despite periods during which they may lag.

This discussion will not deal with the technical side of radio, but it is hoped that it will offer some aid to those interested in whether radio can help in their operational work.

There are two kinds of radio to which attention will be called: amplitude modulation (A.M.) and frequency modulation (F.M.). In A.M. the carrier wave has a fixed frequency, with signal modulation obtained by varying the strength of the current. In F.M. the carrier wave has a varying frequency, with signal modulation furnished by the variations.

Each type has advantages and disadvantages. With A.M. a lower frequency is normally used, and its wave may be deflected to a limited extent. It is commonly used by most of the present radio stations for commercial broadcasting.

Higher frequencies are normally employed by F.M. Its waves closely follow the line of sight. They will rebound readily, are much less subject to interference through outside noise and static than A.M., and are not easily damped out by overhead structures and high-tension transmission lines. Because F.M. is credited with providing greater clarity of tone, it is also beginning to enter the commercial field. For water departments, F.M., if properly handled, is preferable to A.M.

Generally speaking, three types of service can be utilized: (1) one-way transmission, in which a call is made from a fixed station with no response, (2) two-way transmission in which a call is made from a fixed or mobile station, either of which can originate the call and can freely communicate with the other and (3) "three-way transmission," in which, in addition to two-way communication, the mobile units can communicate with one another without going through the fixed station.

Of these methods, two-way transmission answers most of the requirements and needs only a limited capital investment. Its use demands that all mobile stations either be in service or be reported to the fixed station as out of service. The operator of any mobile station can call the fixed station, which is always manned, and report that Number X (normally a mobile unit) is to be asked a certain question or told to report at a certain place. The question or order is then repeated by the fixed station to mobile unit Number X, and the answer given by X relayed immediately to the first unit. The clearance by this unit is an acknowledgment that the question is

answered or the order has been received. Though not as convenient as three-way transmission, this method does keep the air clear for use by others.

There are stringent rules governing the use of radio. These are designed to prevent the cluttering of the air with ordinary conversation. They are simple to learn and easy to comply with. All operators of either fixed or mobile units must take a licensing examination, which offers no bar to any one capable of being entrusted with departmental matters, and which can be readily prepared for and passed by such a person.

The FCC rules previously published in the JOURNAL are concise in setting forth the requirements for application, installation and operation of any F.M. station. If these rules are followed exactly, little trouble will be encountered. Of necessity the allocations of various bands must be subject to change until the FCC has time to make final allotments confining the various types of users to a frequency range suitable to the operations involved. It does not matter what band the FCC finally allots to the group of utilities that includes water, unless a plant is already equipped. Even such plants will find the expense of adjustment very small.

Beside the present use of radio by police, fire departments, and utilities other than water, there is a growing desire on the part of commercial enterprises for the right to use radio. Some of their demands are receiving favorable consideration, and certain bands will probably be allocated for their use. Water works systems are interested only in having a band allotted within which they can operate. The FCC will make this allocation, either temporary or final, and then those who want radio should at once submit their application; otherwise they may find that in their area the band is fully occupied, and authorization will be difficult to obtain.

The cost of installation will vary largely with the size of the system installed. In Seattle the over-all cost of the main or master fixed station, together with its antenna and connections, was $7,382.46. This service, which is used in common by the municipally owned water, light and transportation departments of the city, consists of one master station, seven fixed auxiliary stations, and 42 cars and trucks fitted as mobile units. It is a two-way transmission system.

The fixed auxiliary stations cost approximately $1,250 each, and each mobile unit costs about $550 to equip. More mobile units may be added as required, until the limit, which is determined by the capacity of the fixed units, is reached.

The costs of operation and maintenance vary in accordance with the type of equipment installed, the care it receives and the use to which it is put. The Seattle Water Department's share of the total cost of operation for 1946 was $793.55, and $692.25 was expended in the maintenance of two fixed and nine mobile units.

There has been a curious development since the earth passed through a meteoric field in October 1946. Since then, for some reason, the Seattle receivers frequently hear stations in Georgia transmitting orders, and, judging by the remarks made in Georgia, Seattle stations in turn clutter up their reception at times. The department has been greatly puzzled by this clear audibility of a station with a theoretical maximum range of 200 miles. All sorts of explanations have been given, the most

frequent being that some sort of a dust belt exists above the surface of the earth and acts as a reflector, bouncing the radio waves back on a wide angle.

What the service of radio will do for any water department is substantially to extend all over the area served the ability to give and receive information and orders as though both parties were in the same room talking to each other. Radio is especially valuable in those situations in which even seconds of time saved can result in reducing damage that may be occurring. It is far better in such emergencies than the telephone upon which we depend so much.

To sum up, an investment in radio is justified whenever considerations of prompt service and the saving of high-priced labor outweigh the costs of installation and operation. A decision in favor of the use of radio will seldom be a mistake.

Control of Slime Growths in Transmission Lines

By Ray L. Derby

A paper presented on July 22, 1947, at the Annual Conference, San Francisco, by Ray L. Derby, Prin. San. Engr., Dept. of Water and Power, Los Angeles.

THE effect of corrosion and tuberculation on friction coefficients and metal pipeline capacity is common knowledge. The increased use of concrete pipes and concrete linings for metal pipes has greatly lessened this difficulty, and for many years it was even thought that such lines would hold their original capacities indefinitely. Unfortunately, this optimism has not been entirely justified. In many lines, capacities have been gradually reduced and pumping heads increased, frequently with no apparent increase in roughness of the interior of the pipe. At times, however, heavy growths of *Crenothrix,* fresh water sponges or other types of organisms have been observed. Though often not readily noticed when pipes are inspected, these organic growths may cause an increase in friction that will seriously affect the capacity of the line. To restore the original capacity of such lines, treatment of the line or the water, either periodically or continuously, becomes necessary.

The efficacy or efficiency of a given method of treatment may sometimes be very difficult to evaluate properly because of lack of accurate knowledge of the pipeline characteristics. Considerable time and care is frequently taken in selecting a value of C or n for the design of a given pipeline. The line may then be built and no further attention paid to it until, after some years, the capacity is found to be seriously reduced. Treatment for the removal of growths may then be undertaken, but, because the actual value of C was not checked against the design value when the line was first placed in use, reliable information on how much of the original capacity has been restored will be lacking. Within the author's experience, such instances appear to be in the majority.

The author's first encounter with organic growths occurred many years ago. A 14-in. riveted steel line approximately 7,500 ft. long was laid from an aeration and booster pumping plant to a water tower. The design value of C was taken as 100, but no check was made after the line was placed in service. The water contained a considerable quantity of hydrogen sulfide, most of which was removed by aeration. A heavy growth of the sulfur bacteria, *Beggiatoa,* resulted in the aerator. The growth gradually found its way into the pipeline and caused tastes and odors.

Within three years the capacity of this main had dropped off and pumping pressures had increased. Inspection of the pipe interior showed only a very small amount of tuberculation, but there was a fairly heavy coating of slime containing a large amount of *Beggiatoa.* A flow test was made on the line about this time and the value of C found to be 65. It was decided

to use chlorine in an effort to eliminate entirely the hydrogen sulfide remaining in the water leaving the aerator. A dose of 9 to 12 ppm. was used and the pumping pressures were gradually reduced.

Unfortunately, no further flow tests were made on this line, as the slime coating was not at that time considered to affect the rate of flow significantly. It is of great interest, however, to note that several weeks of chlorination at this high dose were required before a residual was obtained at the water tower. Chlorine had apparently improved the carrying capacity of the line and it is to be regretted that more data were not gathered at the time. Subsequent filtration of this supply apparently eliminated any further trouble from *Beggiatoa* and slime growth.

The beneficial effect of chlorine in the control of slime growths is well demonstrated in the excellent paper by M. E. Rogers on his experience at Wichita (1). Arnold at San Francisco has also had success in the use of chlorine and chloramine to control *Crenothrix* and other slime growths (2, 3). In the Hetch-Hetchy Coast Range tunnels a very heavy growth of these organisms was encountered. Within a period of three weeks the flow was reduced as much as 30 per cent. When applied to water from only one source of supply at a time, chloramine treatment appeared to give the best results, but when the soft water from the Sierras was mixed with the harder local water from the Calaveras watershed, chloramines failed to control the growth effectively for some unexplained reason, even though the residual was maintained at 0.5 to 0.6 ppm. For the past few years chlorine alone has been used. Doses of 1.6 to 2.4 ppm. are employed and a residual of 0.35 to 0.75 ppm. is maintained at the lower tunnel portal. It was found that a minimum of 0.35 ppm. must be maintained at all times to control the growths.

Comparison of Cleaning Methods

Chlorine is not always a panacea for the ills caused by biologic growths in transmission lines. Often other chemicals, or even mechanical means, must be resorted to. The choice may often be dictated by the relative cost of the various materials. A. A. Webb of Riverside, Calif., after trying chemical methods, found the periodic use of mechanical scrapers to be much cheaper (4). His company operates an irrigation system which includes a 7,000-ft. siphon across the Santa Ana River. This siphon consists of two centrifugally cast concrete pipes, 48 in. and 42 in. in diameter. The design value of *n* in Manning's formula was taken as 0.013. Shortly after completion of the lines, the actual *n* was found to be 0.012. The water entering these lines is from Warm Creek, which receives the flow from the sewage plant of the city of San Bernardino, Calif. The sewage constitutes from a third to a sixth of the creek flow. Wells are pumped into the creek, and the water is later diverted into an irrigation canal which subsequently enters the siphon. Other wells also enter the siphon at five 27-in. risers. The canal is enlarged to a depth of 8 ft. for a quarter of a mile before it connects with the siphon, and thus acts as a settling basin. At maximum flow, the velocity in this basin probably does not exceed 0.5 to 0.75 fps.

Shortly after placing the siphon in operation, it was noticed that the water in the enlarged section was backing up. Test runs were made and the value of *n* calculated opposite each of

TABLE 1

Effect of Chlorine Treatment on n

Riser No.	Value of *n*	
	Before Treatment	9 Days After Treatment
1	0.019	0.016
2	0.018	0.015
3	0.016	0.015
4	0.014	0.013
5	0.013	0.012

the five risers, with the results shown in Table 1. Both pipes were in approximately the same condition. Investigation showed that, except at the crown and the invert, the interior of the pipes near the upper end was covered with a growth like "the hair on an Airedale's back." The absence of growth at the top and bottom was considered as due most likely to the scouring action of sand and floating debris. At first it was thought that the growth was a moss of some kind, but when the material was allowed to stand over night, many small, black insects were observed and were identified * as *Limnophora*. In the larval state, these insects are aquatic and build their pupal cases on the sides of conduits by cementing silt and other suspended material together. As the growth appeared to be heaviest at the entrance to the siphon, it was evident that the insect eggs were deposited in the settling basin and later carried into the siphon.

Treatment with copper sulfate was tried initially. To a flow of 1,300,000 gph., 200 lb. of copper was added the first hour, and 100 lb. per hour was added for the next five hours—a dose of 18 ppm. and 9 ppm. respectively. After one week the value of *n* for the line was tested, but no improvement was observed; in fact, the line was slightly worse than before. Chlorine was tried next. Several cylinders were connected together and discharged simultaneously into the water. Approximately 1,000 lb. in ten hours was used, to give a dose of approximately 9 ppm. The line was tested nine days after this treatment and the improvement shown in Table 1 was noted. In about two months, however, a new crop of insects was at work, and the capacity of the line was again impaired.

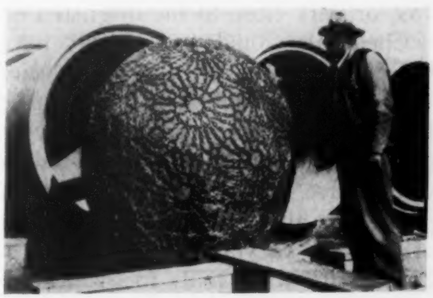

Fig. 1. Air-inflated Rubber Ball for Cleaning Pipelines

As chemical treatment was quite expensive and without permanent effect, it was decided to try mechanical means. Large rubber balls covered with chains (Fig. 1) were placed in the siphon, inflated by a portable compressor, and carried through by the force of the water. No tests were made to determine *n* after this treatment, but the water level in the settling basin dropped approximately 18 in. immediately after the ball emerged from the siphon. This method has been very satisfactory so far and entails very little cost or inconvenience. Treatments do not take place on a regular schedule but only when a decrease in the capacity of the siphon becomes apparent.

* By R. F. Goudey, Cons. Engr., of Los Angeles.

Mechanical cleaning also proved more advantageous than chemical treatment for a city in the mid-south. A pipe 5 ft. in diameter and 50 miles long lost 11 per cent of its capacity due to growths of the fresh water sponges *Asteromeyenia plumosa* and *Trochospongilla leidyi.* These growths were so heavy that manual cleaning would have yielded a wheelbarrow load per foot. Balls were used and capacity that originally cost $500,000 and appeared lost was restored at a total cost of $5,000. The value of *C* before cleaning was 95; after cleaning it was 139, or very close to the original 140.

Chemicals would undoubtedly have killed the growths, but the low velocity (less than 2 fps.) would not have flushed them out readily, and very likely objectionable tastes and odors would have resulted. On the bottom of the pipe there were also many beds of mussels, varying from pea size to 2-in. shells, which only mechanical or manual methods could remove.

San Diego Experience

San Diego, Calif., has found both copper sulfate and chlorine necessary to control pipeline growths, local conditions determining which chemical is used. Trouble has been encountered in the Dulzura Conduit, Hodges Conduit and the Otay-Bonita Pipelines (5).

The Dulzura Conduit is 11 miles long, consisting of an open concrete flume for 8.4 miles, 17 metal flumes totaling 0.8 mile and 17 tunnels totaling 1.8 miles. The maximum capacity is 30 mgd. Two types of growths—one long and filamentous, the other a short, bulbous "moss"—have created sufficient resistance, particularly during warm weather, to cause a spilling at the metal flumes. It is said that loss of capacity sometimes exceeds 15 per cent, but accurate figures are not available. Copper sulfate has been applied every four to six weeks at the upper end of the conduit and occasionally at the half-way point. In dealing with very heavy growths, a follow-up dose is employed after ten days. The usual application is 2,000 lb. per treatment. Yearly cost is about $1,000 with the copper salt costing 6.5¢ per pound.

The Hodges Conduit is 4.65 miles in length and has a maximum capacity of 13 mgd. Except for 23 metal flumes totaling 600 ft. in length, the rest is open concrete conduit, similar in size to the Dulzura. The same type of growth is also found as in the Dulzura Conduit and for the same apparent reason. Loss of capacity, though not definitely known, is estimated at 20 per cent in the worst stages. A measure of control is afforded by the use of copper sulfate at intervals of from two to four days. Because of the very high alkalinity of the water (approaching 200 ppm.), small, frequent and well-distributed doses must be used. These are applied in 25 to 100-lb. batches at several points along the conduit. Copper carbonate forms very rapidly because of the high alkalinity, so that the effect of the copper ion is of very short duration. A good "burn" is obtained for a few hundred feet below the point of application, after which there is a marked decrease in effectiveness. Dosage is therefore applied near the critical flume sections.

During the summers of 1944 and 1945 copper sulfate, even in heroic doses, seemed to have little effect. Crews were sent in to drag the critical sections with chains and steel brooms, a method which gave immediate relief. The product Ben-O-Clor has also been tried, but without much success. Hodges Conduit water is intended for domestic consumption and

noxious chemicals must therefore be used with great discretion. A test patch of the conduit was treated in 1946 with a paint containing 12.4 per cent cuprous oxide (W. P. Fuller Anti-Fouling Paint). Growths after treatment were somewhat sparse throughout the conduit, but when they did occur, were as numerous on the treated sections as elsewhere. The test's result was therefore negative.

Treatment costs for this conduit have averaged about $700 per year for copper sulfate. Mechanical cleaning is estimated at about $40 per 1,000 ft. of conduit.

The Otay-Bonita Pipelines have a total length of 27.5 miles, consisting of 8.1 miles of 40-in. steel pipe, 8.1 miles of 36-in. steel pipe, 8.3 miles of 28-in. steel pipe, and 3.0 miles of 36-in. cast-iron pipe. The capacity of this system is not definitely known, because there are many inter-connections, but it is estimated at between 25 and 30 mgd. The system has suffered not from decreased capacity but from the occurrence of lactose fermenters at the city end of the mains. Formerly, with chlorine residuals of 0.6 to 1.0 ppm. in water leaving the Otay Filtration Plant, a gradual increase in lactose fermenters occurred near the city. Heavy chlorine dosages were then applied during periods two to ten days long at intervals of six to eight weeks, until a residual of 0.3 ppm. could be obtained in the city. At present the residual at the filter plant is maintained at from 1.5 to 2.0 ppm. The entry point residuals vary from 0.25 to 0.4 ppm., and lactose fermenters have practically disappeared. The chlorine dosage is about 2.4 ppm.

Los Angeles Aqueduct

The Los Angeles Dept. of Water and Power has had some difficulty with slime growths, principally in the aqueduct between Haiwee and Fairmont Reservoirs. This stretch of aqueduct, approximately 134 miles long, consists of steel siphons, a covered concrete conduit, and concrete-lined tunnels in varying lengths. Because of wartime demands it has been necessary to carry peak flows much of the time during late spring and early summer. In 1943 it was noticed that there appeared to be a gradual, sustained decrease in capacity from 490 cfs. to as low as 465 cfs. at times. During the month of August 1943 a check was made at Rose Valley (Sta. 107 + 91 below Haiwee Reservoir), and the over-all value of Kutter's *n* was found to be 0.0137. Two tons of copper sulfate

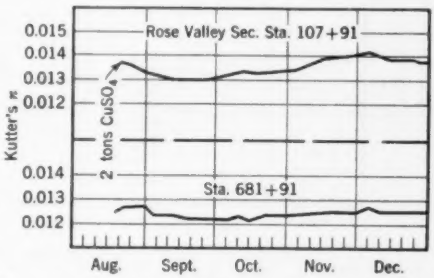

FIG. 2. Aqueduct Flow Coefficients in 1943

were added at Rose Springs, Sta. 104 + 18, on August 23, which resulted in a gradual increase in flow and decrease in *n* to a value of 0.0130 on September 10 (Fig. 2). This value was maintained until about the first of October, when a gradual increase again set in. By December, *n* had reached 0.0140. No further treatment was given at this time, since with the winter rains the water demand lessened. The effect of this treatment was felt as far as Sta. 681 + 91, where *n* dropped from 0.0127 just following treatment to 0.0123 by September 20, but then rose to 0.0125 in December. After this no further effects appeared.

In 1944 it was again necessary to bring more water through the aqueduct because of heavy summer demands. On May 9 an application of 2 tons of copper sulfate brought an increase in flow until June 10, after which it again dropped off. A second dose of 5.25 tons on July 18 caused some improvement, but by the middle of September *n* was again on the upgrade (Fig. 3). The reduction in water demand caused by the coming of the fall rains made additional treatments unnecessary. The treatment given during 1944 was not as successful as that of the previous year, a fact which may be due to dissimilar concentrations of copper resulting from variations in the time required to add the chemical. No records, however, are available.

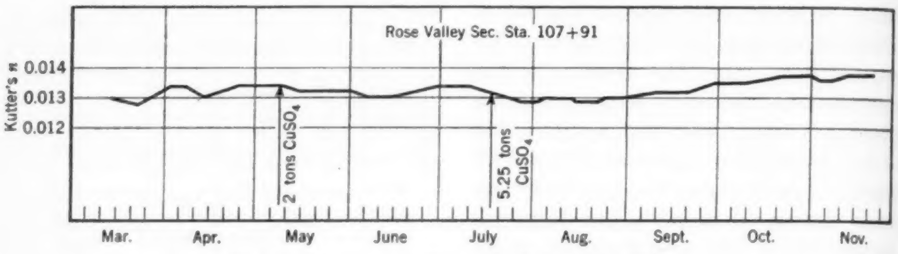

Fig. 3. Aqueduct Flow Coefficients in 1944

In 1945 it was decided to try heavy doses of chlorine instead of the scarcer and more costly copper sulfate. Two tons of chlorine was added May 2 at Rose Valley over a period of about 6 or 8 hours, giving an approximate dose of 5 to 6 ppm. At this time the value of *n* had been about 0.0135 for some weeks. By May 23 *n* was reduced to 0.0130 where it remained until the middle of July, the last date recorded (Fig. 4). No check was made on the dose below Sta. 107 + 91.

Chlorine was also employed on June 12 at Pinto Gates in the Mojave Div. of the aqueduct, about 80 miles below Rose Valley. At this point the aqueduct is a covered-box conduit. During periods of high flow, it frequently overflows at manholes, threatening to wash out embankments. The constriction of flow is partially due to the rough bottom, but it was thought that slime growths might also be to blame. The day following treatment, *n*, which had been fairly constant at about 0.0125 or 0.0126 for some time before, suddenly *rose* to 0.0133, but dropped to 0.0126 or 0.0127 the next day, and remained at that level until the middle of July, after which no further observations were made. The sudden increase in *n* might be accounted for by a temporary swelling of the slime immediately after chlorination. The chlorine was added over a period of 2 to 3 hours, a dose of about 12 ppm. This treatment had no marked beneficial effect on the flow, perhaps because the rough bottom in this section is the governing factor. For that reason, no subsequent attempts have been made with chlorine.

In 1946 the aqueduct was treated three times with copper sulfate. On June 3, 6 tons was added over a period of 6 hours at Rose Springs, a dose of about 20 ppm. A second treatment of about the same dose was applied on July 24, with 5 tons in 5 hours. The third treatment was about August 20, when 7 tons in 8 hours

was added, a dose of approximately 16 ppm. The first treatment reduced n from 0.0140 on June 1 to 0.0129 on July 13 (Fig. 5). This was followed by an increase to 0.0136 on July 27, a decrease to 0.0133 on August 17, and then a slight increase. From that date to September 10, n decreased to a value of 0.0131, after which there was again an increase. The flow during this period increased from 457 cfs. on June 3 to 475 cfs. on July 24 and 477 cfs. on August 20, an improvement in capacity of more than 4 per cent.

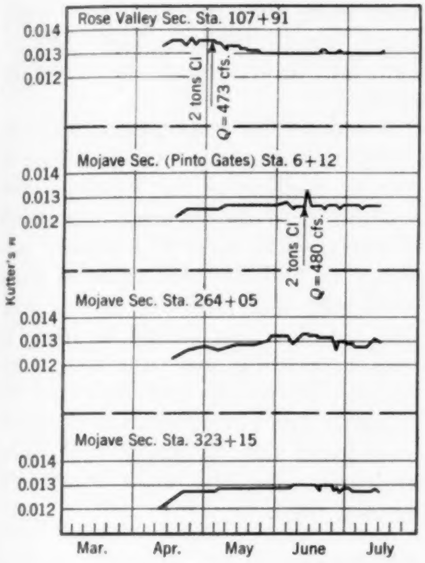

FIG. 4. Aqueduct Flow Coefficients in 1945

The effect of these treatments was quite noticeable at Sta. 433+ 96. At Sta. 681 + 99, the effect of the first treatment was slight. At Pinto Gates in the Mojave Div., the effect on n was adverse, its value actually increasing. It had been hoped that the use of copper sulfate just below Haiwee Reservoir would have the effect of removing the slime growths not only from the aqueduct, but also from Fairmont Reservoir. It is apparent from the records, however, that the distance is too great and the alkalinity of the water too high for this to be accomplished. The copper sulfate dose must be made as concentrated as possible to obtain good results at a distance, because there is then less chance for the alkalinity of the water to precipitate the copper.

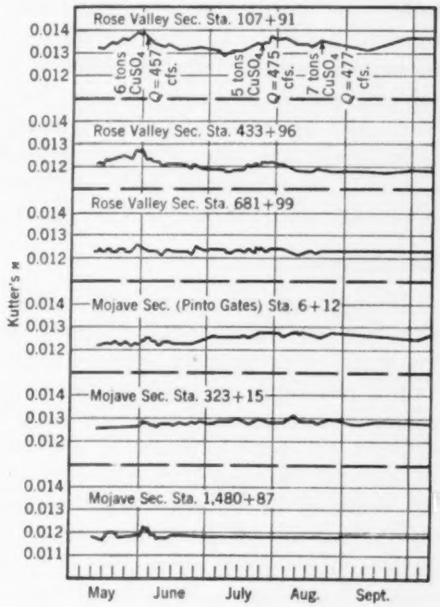

FIG. 5. Aqueduct Flow Coefficients in 1946

Although chlorine has not been quite as satisfactory as copper, the difference in price warrants further experimentation. Chlorine doses much smaller than 10 ppm., if used over a longer period, might produce worthwhile results at less than the cost of copper sulfate treatment. When chlorine has been used elsewhere in the system with residuals of 0.2 to 0.3 ppm., little slime has been noted at the point of application, although

heavy growths were observed in the pipe ahead.

Cost figures for the chemicals alone favor chlorine, which costs \$65 per ton, compared to \$155 per ton for copper sulfate. Labor requirements also favor chlorine slightly. The copper sulfate must be added manually, unless at least a semipermanent feeding station is built and equipped. To add chlorine, the valves on the cylinders are turned and little else need be done unless the weather is cold, when heat must be applied. Copper sulfate may be more accurately fed than chlorine in an emergency, however, because, unless scales or some type of chlorinator is available, the rate of chlorine feed can only be estimated, and no check is possible until the cylinders are empty.

Conclusions

Biologic growths seriously reduce the flow in many long pipelines or conduits. Though permanent elimination is not always possible or practicable, adequate control may not be too difficult or costly. Where conditions permit, the mechanical cleaning of pipes or conduits of circular cross-section by the use of special devices such as balls and chains is often the method most economical in time and labor. For long conduits of varying or irregular cross-section, however, chemical treatment may frequently be cheaper and more practical. In such lines, when taste and odor problems are not involved, periodic treatments may be sufficient to get by a period of high demand. If the organisms cause tastes and odors, continuous treatment of the water may be necessary to prevent growths from forming. If possible, a thorough study of the organism causing the difficulty should be made, and the most effective chemical treatment used. If the alkalinity of the water is high, copper sulfate may be relatively useless, or its action may not carry the required distance. In open ditches or conduits, however, sunlight may render chlorine ineffective. Other chemicals, such as the chlorinated hydrocarbons, should be used with caution in domestic water supplies, not only because of tastes and odors, but also because of possible toxicity. Even when using such chemicals in a water supply strictly for irrigation, their effect on plants must be carefully checked.

It should be emphasized that, although selecting the proper values of friction coefficients for pipelines and conduits is of the greatest importance to water works men, it is equally necessary to find the true value of these coefficients after the line is in operation. A flow test should be made as soon as possible after the line is installed. If trouble later develops, the efficiency and effectiveness of any treatment given may be much more easily evaluated, and the most economical method used.

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Laying a 36-in. Main Through Traffic

By Sydney J. Benedict

A paper presented on May 16, 1947, at the Pacific Northwest Section Meeting, Victoria, B.C., by Sydney J. Benedict, Principal Asst. Engr., Water Dept., Portland, Ore.

MOST of the industries and the high-value business district of Portland, Ore., are located in the part of the city west of the Willamette River. About one-fifth of the city's population lives in this section, and there are nineteen private water companies and districts in the rapidly growing suburbs outside its western boundary. All water for this area is distributed from two West Side reservoirs in Washington Park which are fed from the intake reservoirs on Mt. Tabor, near the eastern edge of the city.

The capacity of the one 30-in. and three 24-in. river-crossing mains is sufficient for any demand that is likely in the near future; but, for the rest of the distance, the entire West Side supply had been dependent upon a single 32-in. cast-iron main. During times of heaviest demand this main did not carry quite enough water, and, at all times, it carried too much responsibility. Plans for an additional line were included in a construction program for which bonds had been authorized in 1941. The materials shortage following the outbreak of the war forced the postponement of this work until Nov. 6, 1945, when a contract was entered into with the Steel Tank & Pipe Co. Division of the American Pipe & Construction Co., calling for the manufacture and laying of 22,350 ft. of 36-in. id. welded steel pipe, $\frac{3}{8}$ in. thick, with a felt-wrapped, coal-tar enamel coating.

A straight line between the reservoirs on each side of the river just about cuts the city in half from east to west, and the installation of a large pipe along this line promised serious interference with traffic. As an indirect route would offer no advantage, however, the direct route was adopted. A week after the contract was signed, work was begun on the construction of a new inlet chamber at the West Side High Gravity Reservoir.

In spite of mill and shipping strikes, the contractor succeeded in obtaining delivery of the necessary steel plates, and shop fabrication proceeded steadily after starting on December 20, 1945. Hauling of pipe began about the first of the year, in loads of four 32-ft., 2,700-lb. sections. It was unloaded from trailers, by truck-mounted cranes, close to its final position in the line and placed on parkings or along curbs. All handling was carefully done, and the only damage to pipe coating occurred after working hours under rather unusual circumstances. Small boys had hit upon a game that was played by rolling the contractor's lighted bomb flares back and forth through a length of pipe. Spilled burning oil ignited the coating and, by the time the firemen arrived, a real blaze had to be extinguished.

Excavation and Pipe Laying

Field assembly of the pipe began Jan. 5, 1946, at the West Side river connection and proceeded west about one mile on southwest Market St.—a street that carried only light traffic but crossed several heavily traveled arteries, among them Pacific Highway 99W on 4th Ave. While excavating and pipe laying equipment were in operation, the blocks affected were barricaded and closed to through traffic. Barricades were removed as the work moved on.

The first stage of excavation was performed by a recently developed pavement breaker (Fig. 1). The active unit of this machine, which was mounted on a light 3-wheel trailer, consists of a cylinder and 6-in. diameter piston having a 40-in. stroke. An 8 × 12 in. cylindrical striking head on the bottom of the piston was bored to take the shank of a 3 × 3 × 5-in. square-edged punch. A hose connection from an air compressor furnished the power for the triphammer and also for an air motor which drove the trailer. This piece of equipment broke the pavement over the whole job and had no trouble keeping ahead of two, and sometimes three, hoe shovels.

Fig. 1. Rapid Pavement Breaker in Action

As the ditch was dug, the broken pavement was hauled away and the excavated earth piled along the edge, leaving a single traffic lane (Fig. 2).

Access to garages was maintained by tunneling under the approaches to driveways. It is probable that plank crossings would have been preferable and more economical, but lumber was almost unobtainable at that time. Tunnels under street intersections, providing roadways about 20 ft. wide, handled north and south bound traffic with little inconvenience.

The crane used for placing pipe in the ditch was rigged so that the sling cables hung from a single block. This enabled the pipe to be rotated without unhooking the sling and helped in matching the landing holes of the sections. Bell and spigot joints were a close fit. After bolts were tightly drawn up in the landing holes, the bottom of the spigot would clear the bell enough to enter (Fig. 3). The bolt holes were later filled and welded.

Obstructions caused minor changes of grade, and rearrangement of underground utilities was occaionally necessary. Some trouble was avoided and changes made easier by the fact that grades established for the 36-in. line provided about 1 ft. more than the usual cover.

Fig. 2. Excavating Trench With Hoe Shovel

On one occasion, a small, abandoned main that was in the way was neatly disposed of by burning it off at each side of the ditch. The torch operator was somewhat surprised to see melted lead flowing out of the cut, but this

was soon explained—by the telephone company.

Testing Joints

Hydrostatic tests of 50 psi. above operating pressures and not less than 125 psi. were specified, but all welding was tested in advance by a method devised by the contractor. The pipe was tions between dresser couplings, which were spaced about 700 ft. apart.

The contractor obtained permission to backfill, at his own risk, over joints proved tight by the soap test without waiting for tests of the long sections. Perhaps because the clamor to have the streets back in service was not as loud as was expected, this was done

Fig. 3. Lining up Bell and Spigot Joints in 36-in. Pipe

bell-and-spigot, welded inside and out. A ½-in. tapped hole had been made in each bell in the shop. Air at the specified test pressures was forced through this hole to the space between the bell and spigot, enclosed by the welds, while the outside of the joint was painted with soapy water. Hydrostatic tests included one or more of the sections between dresser couplings, which

only occasionally, but the results indicate that such a procedure could be followed with negligible risk and would be justified if speed in opening streets was of sufficient importance.

The hydrostatic tests (Fig. 4) disclosed that there was not a single leak in the welding done on the line. Upon completion of the tests, the section was

backfilled with a hoe shovel, using a blade instead of a bucket.

Difficulties Overcome

From southwest 17th Ave. the line followed the Coast Highway, or Jefferson Street, for 2,000 ft. to Washington Park. The loss of roadway along this stretch caused something of a traffic jam during the morning and evening rush of suburbanites. Turning into the park, a long diagonal crossing of the four-lane highway was made. The roadbed consisted of loose rock and earth, so tunneling was not attempted. Half the crossing was excavated, the pipe completed and the trench backfilled before the other half was opened.

Heavy rains kept the backfilled material so wet that paving was delayed until the work was well along on the East Side. When finally started, it was carried through in a continuous operation. Work on the East Side started from a connection with the river mains at southeast 10th Ave. and progressed east along Harrison and Lincoln Sts. to southeast 60th Ave.

Fig. 4. Hydrostatic Test of Welded Joints

It was necessary to reroute one bus line and to discontinue an electric trolley bus service that traveled Lincoln St. along the east end of the job. Power was shut off because of the danger of cranes striking the wires, and gasoline bus service was temporarily established along another route.

The methods of operation used on the West Side were followed on this side of the river and no exceptional difficulties were met until the last six blocks. Along this stretch, the ties and rails of a street car track had been imbedded in concrete and, when later abandoned, had been covered by another foot of concrete paving. For most of these six blocks the pipeline followed the center of this track. It was not possible to shift the location of the trench because a large water main lay on one side and a sewer on the other. It was here that the high-stepping pavement breaker lost its lead and two additional air compressors, with jackhammers, were called in to assist.

The delay in breaking through this last stretch prevented fulfillment of the prediction made to the traction company of the date when bus service could be restored. After exhausting the time allotted, however—and, presumably, the patience of the bus line's patrons—the line was soon completed. The final test was made on May 24, and the department was assured of no more summers of uncertainty about the West Side supply.

Of course, a large pipeline cannot be laid across a city without some difficulties, and this job was no exception; but fewer complaints were received about the traffic blocks and inconvenience to residents than were expected.

There were no personal injuries to passersby or workmen, and no claims for damage to property. The department's luck even held when a car carrying four sailors and a girl was driven through a barricade and landed safely in a wide place in the ditch.

If more criticism was actually voiced about the condition of the streets than those in charge of the job heard about, the reason may have been that the water department is somewhat sheltered by an organizational peculiarity. In Portland, the City Engineer is also the Water Engineer, and when the City Engineer starts to battle with the Water Engineer he usually stops before knocking himself out.

Chemical Fixation of Oxygen

By David J. Pye

A paper presented on July 24, 1947, at the Annual Conference, San Francisco, by David J. Pye, Research Supervisor, Great Western Division, Dow Chemical Co., Pittsburg, Calif.

THE problem of corrosion in industrial water supplies becomes more serious as the complexities of the industrial process and its accompanying heat exchange increase. One of the production plants of the Dow Chemical Co. at Pittsburg, Calif., using clarified San Joaquin River water at a rate of 1.4 mgd. in extensive heat-exchange equipment, had been subject to serious and expensive tuberculation. Not only did the loss of metal require exchanger tube replacement every 18 to 24 months, but rapid tuberculation growth resulted in severe loss in heat transfer, with a consequent increase in water demand. This condition necessitated a general plant shutdown every three months to clean the exchangers by acidizing. Thus the corrosion costs were the sum of the equipment replacement, excess water consumption, loss of production and acidizing expense.

The corrosion was shown to be caused by a concentration of oxygen in the water at a level near saturation. The effect of carbon dioxide was discounted by the pH of 8.8 and low carbonate content of the water.

Considerable thought was given to vacuum de-aeration and to closing the system to permit the use of inhibitors as methods of eliminating oxygen corrosion. The capital investment of such systems, combined with the fact that both sulfur dioxide and caustic soda are products of the same plant, resulted in the decision to remove the oxygen by the sulfite reaction while maintaining the single-pass system.

Preliminary research demonstrated that the oxygen-sulfite reaction could be completed in about twenty seconds using a minimum excess of sulfite catalyzed by minute traces of cobalt, and that 98 per cent of the corrosion would thus be eliminated.

A treating unit was then installed to dose the full stream of 1.4 mgd. This unit has now been in operation for a period of 18 months and has resulted in a substantially complete elimination of corrosion caused by the water. As the saving in corrosion expense has exceeded the cost of the treatment, the installation has been entirely justified.

Oxygen-Sulfite Reaction

Oxygen reacts with sodium sulfite according to the equation:

$$O_2 + 2Na_2SO_3 \rightarrow 2Na_2SO_4.$$

The stoichiometric requirement for the fixation of dissolved oxygen is 7.9 ppm. of sodium sulfite for each part per million of oxygen. Although the reaction is quantitative, practical considerations

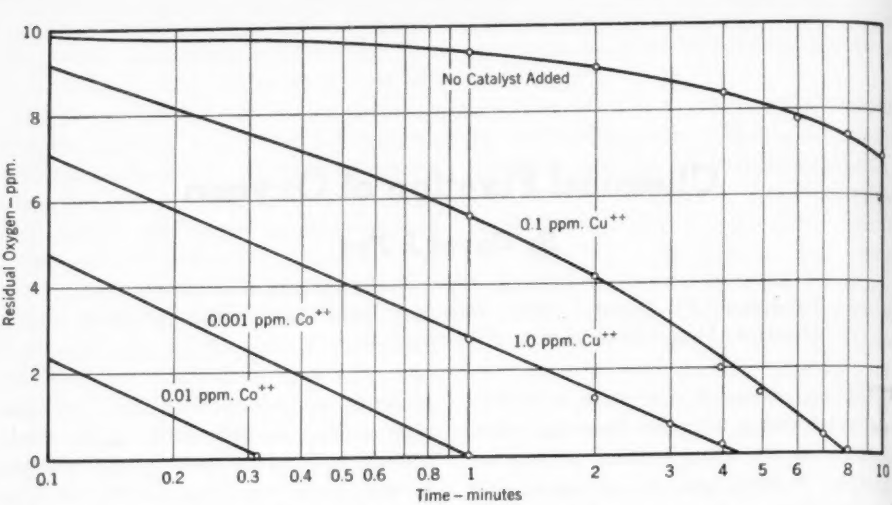

FIG. 1. Effect of Catalysts on Rate of Oxygen Fixation

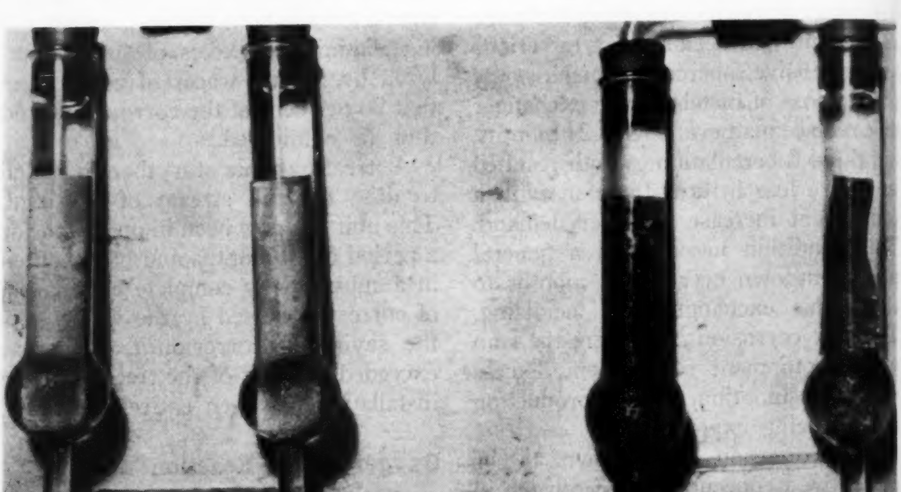

FIG. 2. Appearance of Steel Strips Under Test
(Tubes at Left Contain Treated Water)

of dosing require that an approximate 5 to 10 per cent excess of sulfite be used to insure complete reaction at all times. As the river water under treatment is substantially saturated with air to yield 8 to 10 ppm. of dissolved oxygen, the required dosage of sulfite averages 80 ppm., or 0.67 lb. of sodium sulfite per 1,000 gal.

The reaction between the dissolved oxygen and sulfite ion is extremely slow in the absence of any catalyst, but in the presence of 1 ppm. of copper ion, the reaction is completed in about 5 minutes. Although this method offered a considerable improvement, it was not fast enough to permit dosage into the mill supply line, which had an available residence time of only 30 seconds. Cobalt, however, was found to be a most effective catalyst, requiring only the extremely low concentration of 0.001 ppm., or 1 part per billion, to complete the reaction in one minute, while 0.01 ppm. causes complete deoxygenation in 15 to 20 seconds. The relative reaction rates are shown in Fig. 1. In order to measure them, it was necessary to resort to the dynamic polarographic method of Matheson and Nichols (1) using a cathode-ray oscillograph for instantaneous indication of oxygen content.

Corrosion in Oxygen-Free Water

Steel test strips immersed in a flowing stream of experimentally treated water for 14 days retained their initial bright finish for 5 days, after which a short failure of the dosing apparatus caused a slight tarnish to appear. The control strips, meanwhile, showed the usual rapid corrosion and severe tuberculation. Figure 2 shows the appearance of the strips after 4 days.

Subsequent visual observation of test strips indicated that the original bright surface may be maintained indefinitely, provided oxygen is rigorously excluded at all times.

The relative corrosion rates shown in Fig. 3 were 0.00016 and 0.008 in. per year for the two samples. Although the latter figure, for the control, may not appear excessive, a pitting factor of 7.4 increased the effective corrosion rate to 0.057 or nearly 1/16 in. per year. This figure offered a fair check on actual plant experience, as tube life was seldom more than two years.

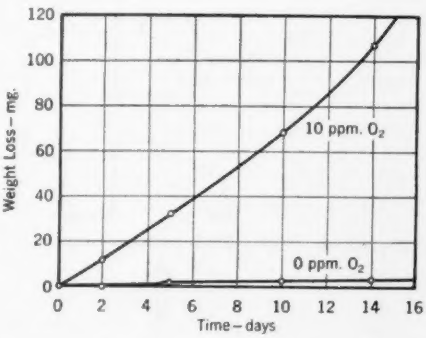

Fig. 3. Effect of Oxygen on Corrosion of Steel

It was evident, then, that a continuously maintained dosage of sulfite with a trace of cobalt would substantially eliminate corrosion of the process equipment.

Treating Unit

The automatic dosing unit is shown diagrammatically in Fig. 4 and in the photograph, Fig. 5. Sodium sulfite solution at about 4 per cent concentration is prepared continuously in a closed 300-gal. tank by reacting a controlled flow of 13 per cent sodium hydroxide with a 3 per cent sulfur dioxide solution, the flow of which is controlled

by a pH recorder-controller set at pH 8.5 to give a normal sulfite solution. A very small drip stream of cobalt chloride catalyst is also added to the mix tank. This tank is equipped with a level control operating the pump recycle. As the pump capacity is many times greater than the dosing stream, it serves as an agitator for the tank, while the level control forces the pump to discharge to the water main any liquids entering the tank.

casional resetting of the sodium hydroxide flow to correspond to changes in plant water requirements.

The contact time necessary for the reaction is obtained by dosing the water main at its junction with the mill supply line so that the oxygen fixation is complete by the time the water reaches the first heat exchanger on the line.

Shortly after the unit was installed, it was noticed that there were slight evidences of tuberculation which indi-

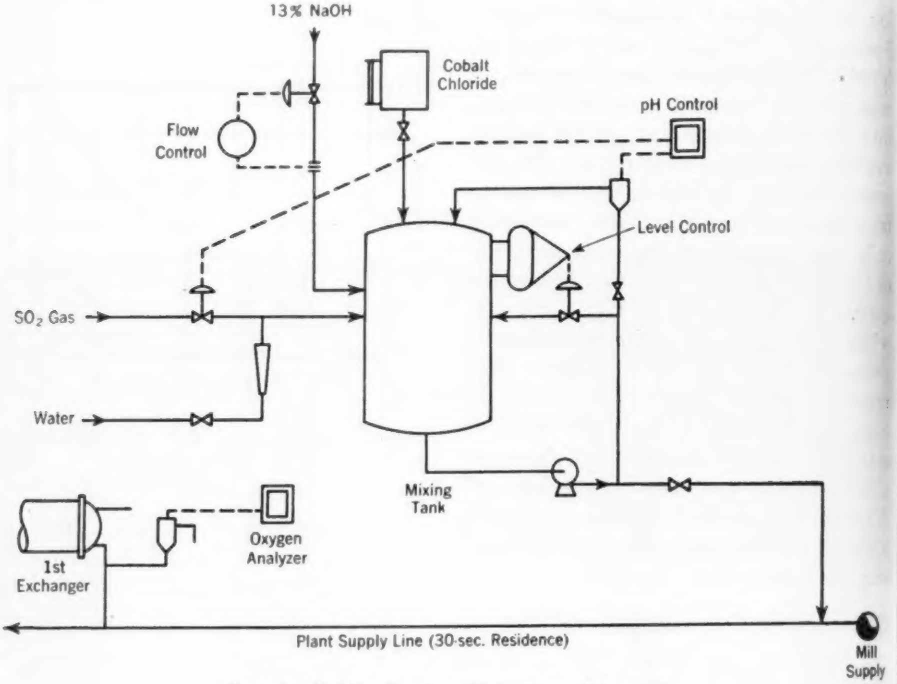

FIG. 4. Sulfite Dosing Unit Flow Diagram

The dosage to the main is fixed by the position of the set point on the sodium hydroxide flow controller, and all other variables adjust themselves automatically with the exception of the catalyst flow, which is not critical and in the quantities used is a low-cost item. The system is entirely automatic and requires no attention, other than an oc-

cated that the dosage was not 100 per cent of requirements notwithstanding the apparently complete fixation results shown by grab Winkler tests. In order to give the operator an instantaneous indication of the dissolved oxygen content, an electrometric oxygen indicator was devised using a platinum measuring electrode and a refer-

ence electrode. The latter consists of a piece of fusible plug metal, which was chosen empirically because it is insensitive to oxygen and gives a zero potential against platinum in the absence of oxygen. When the electrodes are connected to a standard potentiometer recorder through a 1,000-ohm shunt, the measurement covers the full range of dissolved oxygen to saturation. It is sensitive to 0.05 ppm. of oxygen, fol-

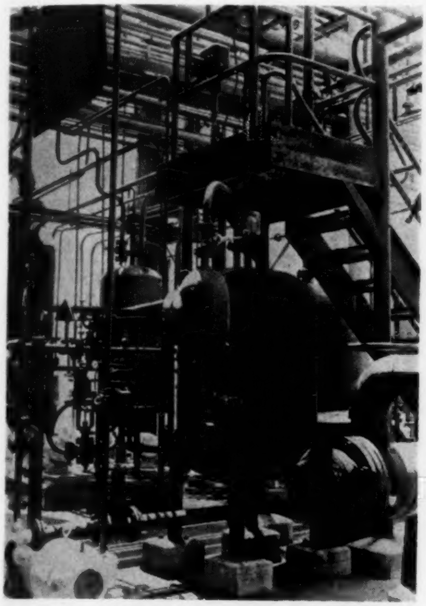

FIG. 5. Sulfite Dosing Apparatus

lowing an exponential function of concentration so that maximum sensitivity is obtained at the low end of the scale. Although the instrument is only semiquantitative, it serves its required purpose well as an indicator of traces of residual oxygen.

The dissolved oxygen recorder revealed that because of occasional pressure surges in the main, the dosage would fall below requirements and remain undetected for very short periods, thus causing a slight corrosion of equipment. Such occurences have been minimized by increasing the discharge pressure of the treating unit.

Results and Costs

Figure 6 shows the severe tuberculation caused by using air-saturated water in a typical exchanger after three months of operation. Figure 7 shows the same exchanger after nine months of service on de-oxygenated water fol-

TABLE 1

Savings Due to Oxygen Removal
(1.4 mgd.)

	Cost per year
Costs of corrosion prior to treatment	
Lost production from shutdowns	$ 7,400
Acidizing expense	3,200
Tube replacements	4,500
Excess water at 3¢/1,000 gal.	4,100
	$19,200
Expense of treatment	
Chemicals	9,600
Amortization of equipment	1,000
	$10,600*
NET ANNUAL SAVINGS	$ 8,600

* Cost per 1,000 gal., $0.0206.

lowing an initial acidizing treatment. Other than a very slight visible film of soft ferric hydroxide slime, there is no evidence of corrosion or tuberculation.

The treating unit has been in satisfactory operation for 18 months at this writing. Tube replacements due to corrosion from the water side have been eliminated; the prevention of tuberculation has resulted in an over-all saving of 20 per cent on cooling water requirements for the plant through increased heat transfer, and plant shut-

downs for acidizing purposes are no longer necessary. Needless to say, the change from an extremely corrosive water condition to complete freedom from corrosion has been a great relief to the operating staff.

A summary of the relative costs of corrosion compared with the expense of oxygen removal is given in Table 1. The costs of corrosion presented do not include the less tangible, but large, items of production lost through unscheduled shutdowns caused by equipment failure, and general corrosion of pipelines, valves and water mains.

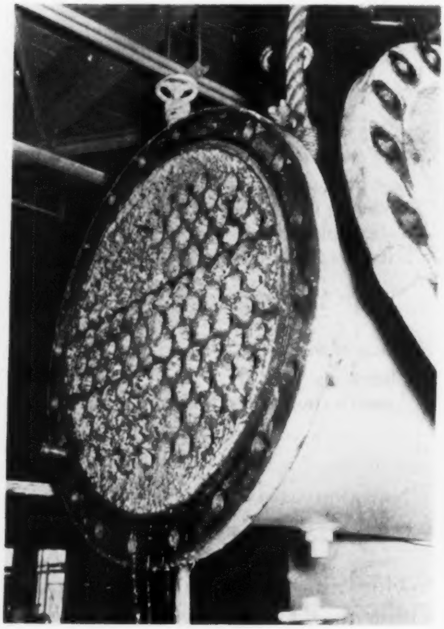

Fig. 6. Heat Exchanger Corroded by Untreated Water

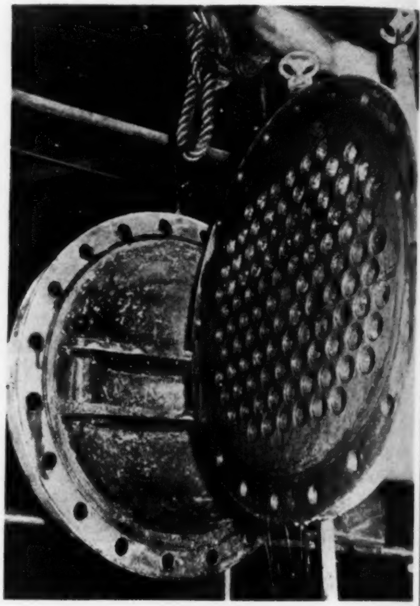

Fig. 7. Exchanger After 9 Months' Service on Treated Water

The chemical costs presented are based on market prices of sodium hydroxide and sulfur dioxide in large quantities in California. The interplant transfer prices of the chemicals were, of course, somewhat less to the particular plant described, so that the actual savings were greater than indicated.

Although sodium sulfite is normally purchased as such for de-oxygenation of boiler waters, the cost would be excessive for a large water supply treatment.

Conclusions

The operation of the de-oxygenating unit has proved its value as a means for substantially eliminating corrosion and increasing water plant efficiency. Now that the effectiveness and desirability of complete deoxygenation has been demonstrated, a larger installation for 14 mgd. is under consideration, which makes use of vacuum de-aeration (2) to reduce dissolved

oxygen to about 0.6 ppm. The remainder will then be completely removed by chemical fixation. Although the first cost of a vacuum de-aeration system is greater than that of a sulfite dosing unit, the net operating costs are less, provided the equipment is suitably incorporated in the mill supply system so that excessive loss of pumping efficiency is not encountered. This combination will guarantee a trouble-free water system at a minimum cost and will result in considerable savings in operating expense.

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Selection and Control of Sampling Points in Distribution Systems

By Kenneth W. Brown

A paper presented on July 21, 1947, at the Annual Conference, San Francisco, by Kenneth W. Brown, Cons. Chemical Engr., Brown and Caldwell, San Francisco.

UNDER the heading "Sampling," the "U.S. Public Health Service Drinking Water Standards" (1) begins: "The bacteriological examination of water . . . shall be of samples collected at representative points throughout the distribution system."

This statement is significant for two reasons. First, it represents the official policy not only of the U.S.P.H.S. but also of the A.W.W.A., and as such establishes a standard procedure for the water supply industry. Second, it displaces the previous emphasis on safety at the source by focusing attention on the quality of the supply as it reaches the consumer. In other words, it recognizes the secondary or terminal hazards introduced by cross-connections, defective plumbing, work on new and repaired mains, open reservoirs and so on, and sets up a program which, if properly maintained, will lead to maximum safety in the operation of public water supplies.

From a practical point of view, it is evident that the control of quality in a distribution system depends on the frequency of sampling and the selection of suitable sampling points. Frequency requirements are set forth in the Drinking Water Standards but the question of location is dismissed, perhaps quite properly, with the general statement that all samples shall be collected from representative points. As a result, it is necessary to know what is meant by a representative point and what steps should be taken in selecting a series of such points for routine sampling.

Selection of Sampling Points

Most of the few principles involved in organizing a suitable sampling program are self-evident; they depend to a large extent on the size of the system and the topography of the service area. Small systems requiring less than six or seven samples per month offer no particular problem, and random sampling at convenient locations is usually sufficient. Systems serving relatively level areas are also fairly easy to handle, provided there are no complications like multiple sources of supply, cross-connections, waterfront hazards and so forth.

If there is a single source of supply and the minimum number of samples is seven or more per month, the simplest arrangement is to divide the distribution system into a series of zones or sections. Zoning for this purpose is largely a matter of convenience, although some thought should be given to division on a population basis, and the collection schedule should be organized to cover the entire system at least once a month. Zoning of sys-

tems operating at one pressure is fairly easy, usually involving nothing more complicated than an arbitrary division of a distribution map into any required number of approximately equal sections. But in most systems, even in flat areas, there are other factors which must be taken into account in planning a systematic zoning program:

1. *Population density.* Since the frequency of sampling depends on the size of the population, it seems only reasonable to assume that population density should be a major item in determining the boundaries of a sampling area. Other things being equal and assuming that the same number of samples are to be taken from each zone, a heavily settled zone should naturally be considerably smaller in area than a lightly settled one. No fixed rule can be given, of course, but selection on such a basis is usually desirable.

2. *Multiple sources of supply.* If two or more sources of supply are available (some systems in California have as many as thirty or forty), zones should be arranged to enclose areas served by an individual source or by a single group of sources. Segregation on this basis is particularly necessary if the areas are separated by a closed valve or a series of valves to maintain required pressure levels.

3. *Cross-connections and other hazards.* Sections having cross-connections with privately owned supplies call for more than ordinary attention, especially if the private supplies are derived from questionable sources. But again there is no fixed rule. Policies in general must be dictated by common sense and a critical appraisal of the potential dangers.

Similar reasoning applies to waterfront areas and the ever-present possibility of obtaining highly polluted water from a shipside connection. Although protective devices are generally available and a great deal of care is taken to prevent any error in making a ship-to-shore connection, due caution must be observed in watching the quality of the supply in the adjacent section of the system. A separate sampling zone should usually be established for this purpose, and samples should be taken at reasonably frequent intervals, perhaps as often as once a day.

4. *Pressure zones.* Distribution systems zoned for pressure purposes should provide for periodic sampling in each of these zones. In systems where population density and other factors are of no special significance, it is entirely possible that boundaries established for pressure zones can be used equally well for sampling zones.

5. *Reservoirs and tanks.* Every program for the collection of samples on a zonal or any other basis should be designed to detect deterioration brought about by storage in uncovered or poorly protected reservoirs and tanks. Policies are governed, for the most part, by the size of the structure and the opportunities for wind-blown contamination or that due to birds. Samples should be taken from a suitable connection directly below the tank or reservoir, with the frequency ranging from once a month to as often as two or three times a week.

6. *Sample collectors.* In most cities of small or medium size, sample collection is an incidental chore assigned to some employee, such as a pump operator or chlorinator attendant, whose daily routine takes him over a large part of the distribution system. Large cities, on the other hand, usually find it desirable to employ one or more

full-time sample collectors, using them, when time is available, for such related functions as treating open service reservoirs and making field tests for turbidity, color, dissolved oxygen and the like. Careful planning is necessary to enable either type of sample collector to get to the right place at the right time.

Control of Sampling Points

After each of the foregoing factors has been duly considered and a general plan developed, the next step is to determine where samples should be taken in each area or zone and whether there would be any point in using special sampling stations protected by lock and key. Personal experience leads the author to believe that, in general, variable rather than fixed sampling points should be chosen. With a zone arrangement, samples can be taken anywhere in specified areas, preferably from business premises and public buildings. Schools are excellent, especially during recess periods when students, who are inclined to be inquisitive, are wandering around. If parking is a problem, a gas station is a good place, as are stores and restaurants with parking facilities. Collection from varied locations open to the public is of particular value because it helps to spread the knowledge of the care being taken in guarding the safety of the local water supply. Sampling thus becomes an effective instrument for the promotion of consumer good will. If for no other reason than the effect on public relations, therefore, a flexible system of sampling points is much to be preferred.

Fixed points, if used at all, should be limited to tanks and reservoirs and to premises likely to be affected by cross- or inter-connections. Whether collection is fixed or flexible, the principal requirement of a sampling program is that it must provide for thorough and regular coverage of the entire distribution system.

There is little need for sampling connections or for special devices which are designed for continuous operation. Continuous sampling and the periodic collection of composite samples may be of some value at a treatment plant, but they appear unnecessary as well as impracticable in a distribution system. Neither is there any system-wide need for special stations protected by lock and key. Stations of this type are best suited for connections installed in locations accessible to the public and therefore subject to damage. A lock-and-key arrangement is desirable principally for samples taken on public property from transmission lines, reservoir outlets, and fixed locations marking a given contact period for a chlorinator.

For convenience in parking, some utilities take as many samples as possible at fire stations, police stations and other fixed points, installing special connections consisting of a valve or petcock and a short length of copper tubing. Though convenient, this method ignores the opportunity of improving public relations. Moreover, experience with numerous and diversified types of supplies indicates that equally satisfactory samples can be taken from an ordinary tap or faucet and that much better coverage can be obtained by random sampling in properly selected zones.

Sample Collection and Shipment

In dealing with the problems involved in the selection of sampling points, it seems pertinent to discuss some technical aspects of sample col-

lection. *Standard Methods* (2) prefers the use of wide-mouth bottles with ground glass stoppers; the so-called mushroom top is typical and most useful. At current prices, however, this type of bottle is relatively expensive and represents quite an investment for laboratories requiring large quantities. Screw-cap bottles with caps made of molded plastic have been tried as a cheaper substitute, but some of these appear to be susceptible to contamination, either from the cap or other causes. Wide-mouth bottles with narrow rims—the kind used for the display of samples or specimens—are also subject to contamination. Certain types of caps have a tendency to fail after repeated sterilization, although no information is available about which plastic material can be depended on for the longest service. If such bottles are sterilized in a steam autoclave instead of an oven, the probability is that almost any kind of molded cap will be satisfactory. The cheapest and most useful of the screw-cap bottles is a 4-oz. French square bottle with a mouth approximately 1 in. in diameter. Caps for these, as well as for any other type or shape, should be fitted with a rubber ring similar to a hose gasket instead of the usual paper insert. Paper and kindred materials may become soft or pulpy after continuous use and are neither as clean nor as serviceable as rubber.

The protection of sample bottles presents a second problem. A cover is essential for glass-stoppered bottles but is optional and usually unnecessary for bottles with plastic caps. Aluminum foil is the best material because it folds around the top and neck of the bottle and requires no string or rubber band to hold it in place. Foil for this purpose should be 0.001 gage (the thickness in inches) and should either be cut in squares or, preferably, in 5-in. circles. Wrapping paper, parchment and other materials of that nature may also be used but are not so satisfactory as aluminum foil.

A third consideration is the practice to be followed when adding a dechlorinating agent such as sodium thiosulfate. All chlorinated supplies should use bottles containing thiosulfate, preferably added in solution instead of in powder form, as called for in *Standard Methods.* The addition to each bottle of two or three drops of solution containing 10 g. of sodium thiosulfate in 100 ml. of water is suitable for all ordinary purposes and is definitely easier than adding an approximate weight of dry powder. Laboratories handling samples from both chlorinated and unchlorinated sources should avoid possible confusion by using thiosulfate-treated bottles for all purposes.

Experience has shown that the flaming of faucets and other sampling connections is generally unnecessary. Permitting the water to run long enough to get a representative sample, which takes about three to five minutes, is sufficient for most purposes and usually serves to eliminate any possibility of local contamination. On the other hand, if a sample shows positive results for coliform organisms and there is no apparent reason for such a condition, it is wise to flame the tap when taking a check sample from the same source.

The questions of storage time and shipping temperature have been treated by Prescott, Winslow and McCrady (3). They present a few figures, all based on the work of others, which point to the desirability of low-temperature storage for a period of not

more than twelve hours. If this condition is essential, as the authors believe, there would have to be a change in the currently well-established practice of sending samples by mail to state and other laboratories serving one or more systems. It can, however, be asserted with a fair degree of assurance that any errors which may occur as a result of the practice are of limited significance and do not endanger the public water supply. Operating evidence accumulated over a period of more than twenty years has consistently failed to show any serious weakness either in the use of central laboratories or in the shipment of samples in un-iced containers. But since there are two schools of thought, it seems appropriate to suggest an impartial and critical study to determine the effect of such factors as storage, transportation and temperature. This might be accomplished co-operatively by a group of laboratories and would furnish authoritative information on an important phase of water works practice.

It should be emphasized that sampling for routine purposes is largely a matter of common sense. Suggestions are useful, but all such programs in their final form are developed by intelligent planning and the proper recognition of fundamental requirements.

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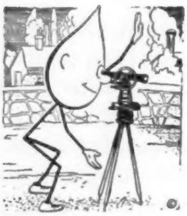

Operating Characteristics of Synthetic Siliceous Zeolite

By L. Streicher, H. E. Pearson and A. E. Bowers

A paper presented on July 24, 1947, at the Annual Conference, San Francisco, by L. Streicher, Chief Chemist, H. E. Pearson and A. E. Bowers, Research Chemists, Metropolitan Water Dist. of Southern California, LaVerne, Calif.

OPERATING exchange capacity, salt economy and life expectancy are the three most important characteristics of a base-exchange material used for water softening. In the course of a systematic investigation of these characteristics of synthetic siliceous zeolites, the staff of the Metropolitan Water Dist. of Southern California has accumulated information which may be of assistance to other members of the water works profession.

Although numerous papers have been written detailing the characteristic properties of zeolites and describing methods for determining the quality of base-exchange minerals, the investigations conducted by the district have revealed a sparsity of useful information on this subject. This lack can probably be attributed to three factors: (1) most zeolite softener installations are relatively small, and consequently do not warrant a research staff to investigate the problems encountered; (2) where the mineral is used for water conditioning in industry, the cost of such treatment is usually such a small proportion of the total cost of the finished product that the manufacturer does not hesitate to replace the mineral in his unit when a loss in capacity is indicated; and (3) because of the competitive nature of their product, most zeolite manufacturers are reluctant to publicize the results of their investigations and research.

None of these conditions affects the district, which has an investment of over $100,000 in zeolite alone for use in the largest zeolite water softening plant in the world. Considerable research expense to protect this investment is warranted. It should be understood, however, that the investigations to date have, in general, merely indicated the direction for further study and should not be considered complete.

Definition of Zeolite

The present-day usage of the term "zeolite" loosely covers a variety of ion exchangers, such as natural greensand, processed greensand, bentonitic clay, synthetic gel-type mineral, carbonaceous exchangers and the newer synthetic resin exchangers. Strictly speaking, only the first four are zeolites by definition. Besides differing in chemical composition, these exchangers differ widely in exchange capacity, ranging from 2,700 grains per cu.ft. for natural greensands to ten

times that capacity for some of the resinous exchangers, with the salt consumption varying through almost as wide a range. This paper will deal solely with the operation and behavior of synthetic, siliceous, gel-type zeolites, the minerals made by mixing sodium silicate with sodium aluminate or alum, or both, in aqueous solution. All subsequent unqualified reference to zeolite will mean this type of mineral.

The information presented herein was derived from laboratory tests and analyses, pilot plant tests, a compilation and study of softening plant zeolite operation records, and a review of the literature available on this subject. Plant operating experience substantiates the data presented in this report. No attempt has been made to include references to all the published work on zeolites, because excellent bibliographies have been presented by others (1, 2). Unless otherwise noted, the data were based on tests conducted with Colorado River water. An average analysis of the water passed into the district softener units during 1946–47 is given in Table 1. A description of the operating procedure which has been found to give satisfactory exchange capacity and salt economy with the district softener units will be included.

Specifications

When the district was preparing to make the initial purchase of zeolite for the softening plant early in 1940, no adequate or complete written specifications were available for synthetic base-exchange minerals. Under the direction of the district's consulting engineers, and with the co-operation of the zeolite manufacturers, specifications were prepared for the definition and type of mineral desired, the weight per cubic foot, moisture content, particle size, material expansion, chemical composition, operating exchange values and methods for testing. Except for a few minor changes, these specifications have been found satisfactory for all purchases of zeolite by the district.

In 1943 the "Tentative Manual of Zeolite Test Procedures" (5Z–T) was approved for publication by the Board of Directors of the American Water Works Association (3). This was the first attempt made to standardize test procedures for the examination and classification of cation exchange materials operating on the sodium cycle. This manual was not intended to serve as a set of specifications, but the procedures detailed therein are an excellent general guide to prospective purchasers who wish to test and compare

TABLE 1

Average Analysis of Metropolitan Water Dist. Zeolite Influent Water, Fiscal Year 1946–47

		parts per million	*equivalents per million*
Silica	(SiO_2)	14.0	—
Iron	(Fe)	0.0	0.00
Manganese	(Mn)	0.0	0.00
Calcium	(Ca)	60.0	2.99
Magnesium	(Mg)	31.0	2.55
Sodium	(Na)	120.0	5.22
Potassium	(K)	2.0	0.05
Bicarbonate	(HCO_3)	68.0	1.12
Sulfate	(SO_4)	335.0	6.97
Chloride	(Cl)	92.0	2.69
Nitrate	(NO_3)	0.4	0.01
Fluoride	(F)	0.4	0.02
Boron	(B)	0.1	0.01

Total Dissolved Solids	685 ppm.
Total Hardness as $CaCO_3$	277 ppm.
Carbonate Hardness as $CaCO_3$	56 ppm.
Hydrogen Ion Concentration (pH)	7.6

zeolites. The need of criteria for the selection of a suitable exchange mineral will become more evident upon examination of the data presented later in this report.

Exchange Capacity

The most important factors influencing the operating exchange capacity of a zeolite are the: (1) chemical composition of the mineral; (2) manufacturing process; (3) grain size; (4) porosity; (5) rate of softening; (6) depth of mineral; (7) hardness of water at end of softening run; (8) quality of water (such characteristics as temperature, suspended matter, pH, per cent of sodium); and (9) salt dosage.

Chemical Composition of Mineral

The factor in the chemical composition of the mineral having the greatest significance for the exchange capacity of a zeolite is the mol ratio of silica to alumina. Walton (1) refers to Mattson's work (4), which indicated that the exchange capacity of a zeolite increases as the $SiO_2 : Al_2O_3$ ratio increases to about 6 : 1, an increase in the ratio beyond this point resulting in a gradual decrease in capacity. A zeolite having a mol ratio of $SiO_2 : Al_2O_3$ of 14 : 1, however, and an exchange capacity exceeding 10,000 grains per cu.ft. has been reported (5). Generally the $SiO_2 : Al_2O_3$ ratio for manufactured zeolites is found to be within the range from 3 : 1 to 7 : 1. Provided that these general limits of silica to alumina ratio are observed, other characteristics (such as grain size or porosity) are more important than chemical composition, if exchange capacity alone is concerned. If the life expectancy of a mineral is considered, the factor of chemical composition may assume greater importance.

Manufacturing Process

Concentration of the reacting solutions, efficiency of mixing, pH of the final mixture and, perhaps most important, the conditions during drying or curing may all influence the physical characteristics and exchange capacity of a zeolite. As a result of tests designed to determine the effect of various drying procedures on the exchange capacity and hydration of zeolites, Larian and Mann (6) reported that: (1) rapid drying rates produce a pronounced case-hardening effect, with the result that surface capillaries are restricted and exchange capacity reduced; (2) for a given temperature, the capacity of a zeolite is increased with increasing relative humidity during drying; and (3) overdrying of the gel produces a zeolite of appreciably lower exchange capacity. Under favorable conditions, satisfactory curing may be obtained by either air drying or oven drying.

Grain Size

As base exchange is essentially a surface reaction, it is to be expected that particle size would markedly influence the exchange capacity of a zeolite. Dolique and Macabet (7) hold grain size to be of such importance that no valid comparison between exchange capacities of different zeolites can be made unless the same particle size is used. Tests with Colorado River water have led to the same conclusion. The data in Fig. 1 represent a typical graph showing variation in exchange capacity with grain size for a zeolite with a salt dosage of 3.5 lb. per cu.ft., water temperature of 65°F., and 60

ppm. of hardness as $CaCO_3$ at the end of the run. It might be inferred from these data that only the smaller grain sizes should be used if maximum efficiency and economy in zeolite operation are desired. An examination of the data presented in Fig. 2, however, at a temperature of 69°F. and using zeolite with a real density of 2.26, shows that the mineral loss by carryover during backwash or in upflow softening could become a serious problem if only the very small grain sizes were used. In downflow operation, the finer materials tend to pack, resulting in an undesirably high pressure loss and channeling. A typical screen analysis of a

TABLE 2

Typical Sieve Analysis of a Commercial Zeolite

Sieve No. U.S. Std. Sieve Series — Passes	Sieve No. U.S. Std. Sieve Series — Retained On	Per Cent by Weight
—	No. 8	0.3
No. 8	No. 10	1.7
No. 10	No. 16	35.0
No. 16	No. 20	30.0
No. 20	No. 30	18.0
No. 30	No. 40	10.0
No. 40	—	5.0

zeolite which has been found satisfactory for upflow softener rates as high as 8 gpm. per sq.ft. is given in Table 2. The expansion upflow rate curve for this mineral is included with the data in Fig. 2.

Porosity

Porosity of a zeolite is most significant when the contact time between water and mineral is sufficiently long to permit outward diffusion of the sodium ions to the surface of the zeolite grains. Thus, the rate of softening determines the degree of influence of porosity upon capacity. Tests conducted by Collins (2) indicated that with a dense zeolite, such as greensand, capacities showed no pronounced change at flow rates up to 10 gpm. per sq.ft., whereas the capacity of a porous, gel-type zeolite varied inversely with the water velocity. The higher exchange capacities obtained in softeners operated intermittently, when compared with those operated continuously, can undoubtedly be explained on the basis of the longer contact time between water and zeolite permitted in the former type of unit.

Rate of Softening

As was mentioned, in any consideration of the exchange capacity of a zeo-

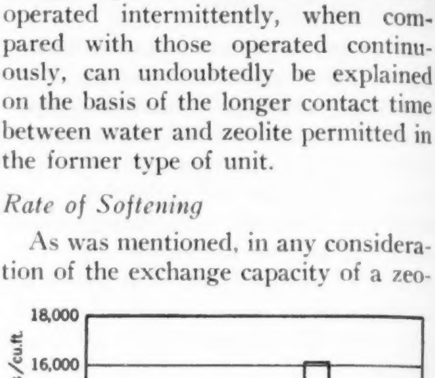

FIG. 1. Effect of Grain Size on Exchange Capacity

* Exchange capacity of commercial zeolite shown in Table 2.

lite, the rate of softening and porosity of the mineral are related. Data are presented in Fig. 3 showing the variation in exchange capacity with downflow softening rate for two zeolites. The salt dosage is 3.5 lb. per cu.ft., the temperature of the water 64°F. and the hardness at the end of the softening run 60 ppm. The increased capacity with decreasing rates of flow for these relatively porous minerals is clearly shown. A similar variation is found with upflow units, except that the exchange capacity is increased by 5 to 20 per cent over the downflow capacity. It may be pointed out that

the flow rates are given in terms of gpm. per cu.ft. rather than gpm. per sq.ft. because the former designation is more truly a measure of the contact time between water and zeolite. The latter designation is of greater significance when the element of zeolite expansion is considered.

Depth of Mineral

The depth of mineral in a zeolite softener is of importance in softener unit design because it influences the total volume of zeolite and, therefore, plant capacity; and because of its relationship to the softening rates used.

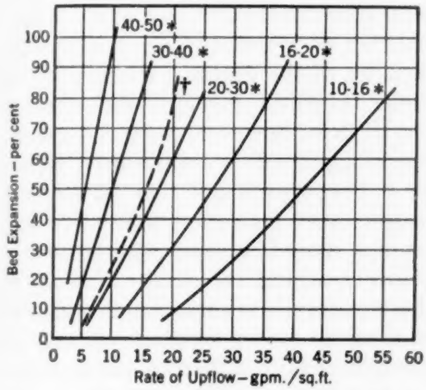

FIG. 2. Effect of Upflow Rate on Zeolite Expansion

* U. S. Std. Sieve Series numbers.
† Zeolite having sieve analysis shown in Table 2.

It has been shown earlier that, although the exchange reaction in zeolite softening takes place on the surface of the grains and is almost instantaneous, a higher capacity is obtained with porous minerals at lower water velocities, due to the increased time permitted for diffusion of sodium ions to the surface of the grains. In addition, however, downflow tests have revealed that even if the contact time between water and zeolite has been kept the same in deep and in shallow units, the former have given higher unit capacities than the latter. Data illustrating this principle under the same conditions of salt dosage, temperature and hardness as in Fig. 3, and with a rate of flow of 3.0 gpm. per cu.ft., are given in Fig. 4. The explanation is probably that each unit quantity of water comes into contact with more mineral particles in a deeper layer of zeolite, so that the likelihood of channeling and premature breakthrough of hardness is reduced.

Hardness at End of Run

Because of the quality of water required, zeolite softeners in industrial plants are generally run only to the

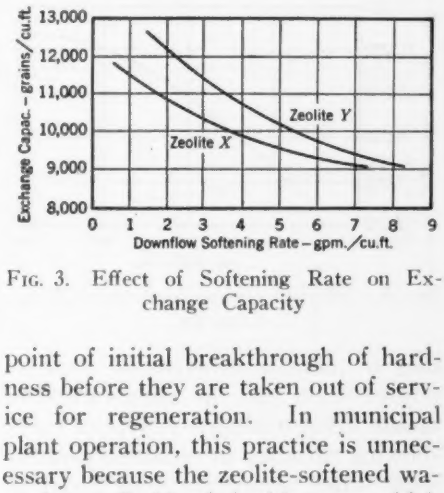

FIG. 3. Effect of Softening Rate on Exchange Capacity

point of initial breakthrough of hardness before they are taken out of service for regeneration. In municipal plant operation, this practice is unnecessary because the zeolite-softened water is usually blended with water which by-passes the softeners. As a result, greater zeolite capacity and salt economy are attained in these installations, for the softeners can be run until the effluent hardness is 60 ppm. or higher. Data corroborating this statement are presented in Fig. 5. The salt dosage, rate of flow and water temperature were uniform throughout the test. Davis (8) reports that no deterioration in the exchange capacity of some greensands was found even when the

softener units were operated to the complete exhaustion of the mineral.

Quality of Water

Of the various elements of water quality, temperature and suspended matter are most noteworthy where exchange capacity of a zeolite is concerned. The per cent of sodium in the softener influent water and the pH also have some influence on the capacity of the exchanger. The effect of other characteristics of waters on zeolites will be discussed in relation to life expectancy.

Within the normal operating range for zeolite softeners, it has been found

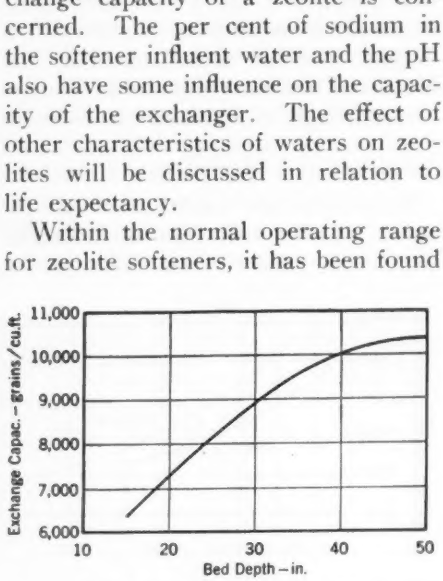

FIG. 4. Effect of Zeolite Depth on Exchange Capacity

that an increase in exchange capacity follows each rise in temperature of zeolite influent water. A typical curve showing variation in exchange capacity with water temperature is given in Fig. 6, under uniform conditions of salt dosage, rate of flow and hardness at the end of the run. An appreciable increase in zeolite capacity with higher water temperatures is apparent. Collins (2) presents data showing a similar temperature effect. He shows, in addition, a gradual decrease in exchange capacity with continued use. He refers to Martin (9), who explained the effect of increased water temperature on zeolite capacity on the basis that the viscosity of the water becomes less with increased temperature, thereby permitting the water to enter the capillary channels of the zeolite more readily, increasing both the amount and speed of the base-exchange reaction.

Suspended matter in water or in brine entering a zeolite softener can be the cause of serious loss of capacity as a result of the mechanical clogging of the zeolite pores. Sauer and Ruppert (10) found that this clogging effect varied with different materials in the following decreasing order: gelatin, gum arabic, Irish moss, soil colloids, dextrins, humic acids, tannin. A contact time of only one hour with concentrations of 0.1 per cent of the materials left no residual effect on exchange capacity of the zeolite. Circulation of these solutions through the mineral for 10 days, however, produced a definite clogging effect and reduced capacity. They concluded that all organic matter other than the humic acids and tannins should be removed from water before reaching the zeolite. Most of these materials are not found normally in domestic water supplies but may be encountered in industrial water treatment. Bacterial slimes, also, may cause clogging of zeolite. A decrease in capacity lasting for several days was caused by regeneration with brine containing fine clay particles at the district plant (11).

An investigation into the effect of water pH on zeolite capacity was conducted by Behrman and Gustafson (12). They reported that, using Chicago water with adjusted pH, the exchange capacity of a synthetic gel-zeolite dropped from 16,000 grains per cu.ft. at pH 7.8 to 9,800 grains per cu.ft. after 56 cycles at pH 6.0. Beyond this point the capacity remained fairly constant at the lower value.

When the pH of the water was raised back up to 7.8, a substantial portion of the lost capacity was restored after a period of time. A moderately high pH, above 8.3, may cause lower capacity by coating or clogging the grains with $CaCO_3$.

Calcium, magnesium and sodium ions, when present together in water entering a zeolite softener, compete for the exchange spots on the mineral. It follows that the more sodium present in the water initially, the more competition the calcium and magnesium would encounter in their tendency to exchange place with the sodium in the zeolite. The result would be a more rapid breakthrough of calcium and magnesium and, therefore, a lower exchange capacity if the initial content of sodium in the water is high. The exchange capacity obtained when only a calcium salt was initially present in a water was compared by Baker (13) with capacities found when both calcium and sodium salts were present. A decrease of about 2 per cent was noted when the initial ratio of Ca : Na was 1 : 1; 18.6 per cent when this ratio was 1 : 2; and 71.3 per cent when it was 1 : 4. In computing the anticipated capacity of a zeolite, most manufacturers use a formula to compensate for the effect of a high sodium content in a water.

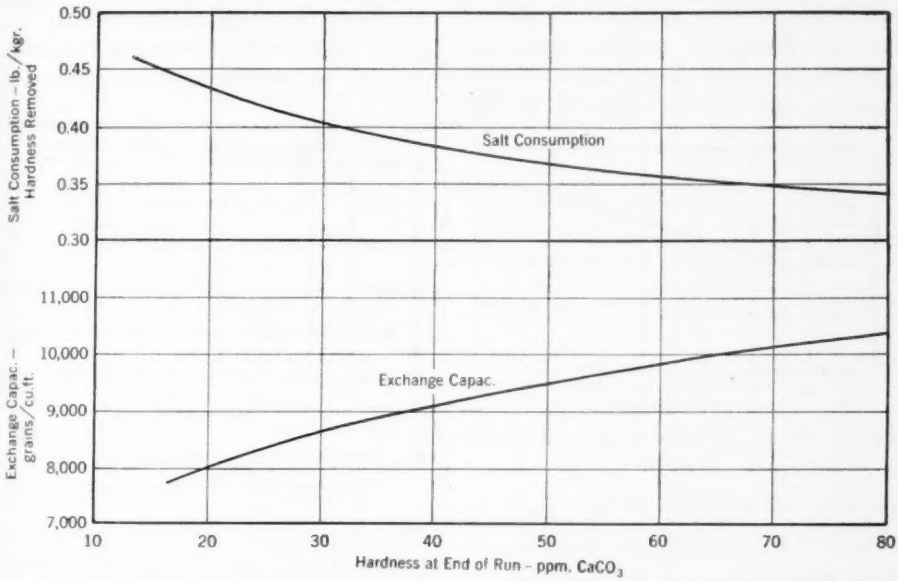

FIG. 5. Effect of Hardness at End of Softening Run on Salt Consumption and Exchange Capacity

Salt Dosage

The difference between operating exchange capacity and ultimate exchange value of a zeolite has been clearly presented by Tiger (14), and the relationship between operating capacity and the quantity of salt used for regeneration was referred to in this discussion. In Fig. 7 data are given showing the variation in exchange capacity with salt used for a 30-in. depth of a specific zeolite with a rate of flow

of 3.0 gpm. per cu.ft. and a temperature of 59°F. From these data, it is evident that *exchange capacity must always be correlated with salt consumption per unit weight or volume of zeolite* to be meaningful. The curve in Fig. 7 shows that as the capacity of a mineral is increased through the use of higher salt dosages for regeneration, the economy of the softening process is decreased. That is, the pounds of salt per kilograin of hardness removed is gradually increased as the salt dosage is raised. Behrman (15) reports that a saving of 33 per cent in salt can be attained at the expense of a 20 to 25 per cent decrease in rated exchange capacity.

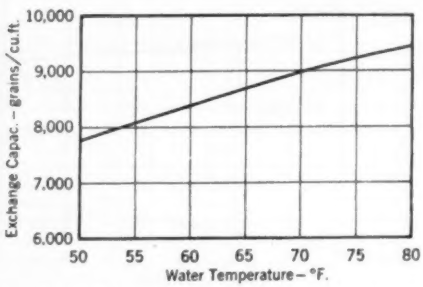

FIG. 6. Effect of Temperature on Exchange Capacity

Life Expectancy of Zeolites

At the present time it is impossible to predict the useful life of a synthetic gel-type zeolite, but a number of factors are known to influence the deterioration of these materials. Mechanical attrition and the loss of silica by dissolution in the water appear to be the principal causes of zeolite aging, but frequently the fouling of the zeolite by calcium carbonate, iron, manganese, inorganic or organic colloidal materials, and bacterial slimes has caused a temporary or permanent reduction in the ability of the zeolite to soften water. In Table 3 it may be observed that some zeolites have been in service as long as 11 years, with 6 mil.gal. of water per cu.ft. softened through the mineral without serious loss of capacity or deterioration of the exchanger. On the other hand, examples are given of severe loss of exchange capacity under different conditions in a period of 5 years with only 1 mil.gal. of water passed through each cubic foot of the zeolite. The time for replacement of a zeolite will depend upon the degree to which the wear on the zeolite actually reduces the exchange capacity to such an extent that uneconomical

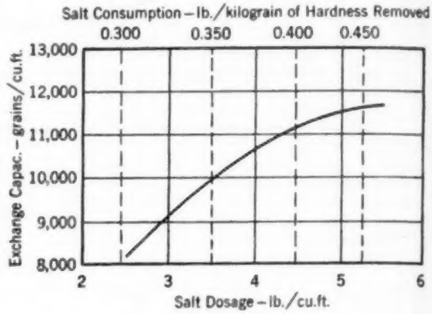

FIG. 7. Effect of Salt Dosage on Salt Consumption and Exchange Capacity

operation results, or the softener capacity limits the output of softened water as the ratio of regeneration time to softening cycle time increases. Sometimes efforts to prolong the life of a zeolite by one of the several revivification procedures described later may be successful and economical.

Mechanical Attrition

The mechanical attrition loss from zeolites seems to vary somewhat due to the hardness of the zeolite granules, but an average attrition loss appears not to exceed 3.0 per cent per year. Table 3 shows the variations which have been observed for several zeolites. Little control over attrition

losses can be attained, and the procedure normally practiced is to skim off the fine zeolite collected on the surface of the beds when this interferes with normal downflow operations. The unit is then brought back to designed zeolite volume by the addition of new mineral.

Silica Solubility

The cumulative loss of silica by dissolution from zeolites over a few years of constant cyclic softening and regeneration operations is one of the major causes of zeolite deterioration. Water is the most important natural solvent in the world. Consequently, the loss of silica from a zeolite, natural or synthetic, varies with the aggressive characteristics of the water being softened, and appears to be a function of (1) temperature, (2) initial silica content of the water, (3) pH, (4) fluorides, (5) total dissolved minerals, (6) the growth of micro-organisms and, perhaps, (7) the age of the zeolite.

Temperature

It has been observed that the solubility of silica contained in either the natural or synthetic gel-type zeolites increases as the temperature of the water rises. Martin (9) presented data showing silica solubility over a wide range of temperatures during an overnight contact period. The results of laboratory studies in which 1 g. of zeolite was agitated in 100-ml. portions of water for 5- and 30-minute intervals over a range of temperatures normally encountered in southern California are shown in Fig. 8. It appears that silica losses in the summer months, when the water temperature averages about 24°C. (75°F.), are likely to be more than twice as large as the losses at the winter temperatures ranging from 12–15°C. (54–59°F.). In a recent paper Owens (16) shows an increased silica-pickup from natural zeolites during the hot summer months which is probably caused, in part, by increased temperatures. In order to show the

TABLE 3

Physical, Chemical and Operating Characteristics of Old Zeolite

Zeolite	Age of Mineral *yr.*	Water Softened *1,000 gal./cu.ft.*	Operating Exchange *gr. per cu.ft.*		Salt Consumption* *lb./kgr. $CaCO_3$* When Tested	Annual Attrition Loss	Silica Content of Water *ppm. SiO_2*	Zeolite Analysis		
			Original	When Tested				*% SiO_2*	Ratio SiO_2:Al_2O_3	Wt. per cu.ft.† Ignited
A	1	200	12,000	9,870	0.36	2.0	10	66.62	6.45	25.1
B	3	790	9,000	9,000	0.40	1.1	9	61.78	4.82	19.5
C	7	970	10,000	9,360	0.38	2.4	16	59.18	5.01	14.9
D	5	1,140	11,000	6,180	0.62	3.0	2–13	58.18	4.20	18.0
E	5	2,140	10,200	8,100	0.45	2.5	8–12	55.70	3.85	20.6
F	11	2,100	12,000	9,870	0.36	2.0	10	61.71	4.67	24.6
G	9	2,500	9,000	9,000	0.40	1.1	9	61.70	4.73	18.0
H	7	3,650	13,300	11,300	0.32	2.5	8–12	63.25	5.50	20.0
I	11	6,400	13,300	9,300	0.34	2.5	8–12	59.89	4.86	19.6

* Initial salt consumption on all new zeolites listed varied from 0.31 to 0.37 lb. per kilograin hardness removed.
† When new, these zeolites weighed 27–29 lb. per cu.ft. on the same basis. Twenty- to 30-mesh zeolite packed by jarring while submerged in water.

effect of changing the initial silica content of the water, the temperature-silica-solubility relationship was determined at two initial levels of SiO_2, 8 and 14 ppm. Figure 8 shows a strong repressive effect on silica solubility as the initial silica content of the water is increased.

Silica Content of Water

Further data showing the effect of changes in the initial silica content of the water on silica losses from a zeolite are shown in Fig. 9. Water at 24°C. was shaken for the time (in minutes) shown to obtain the data. The

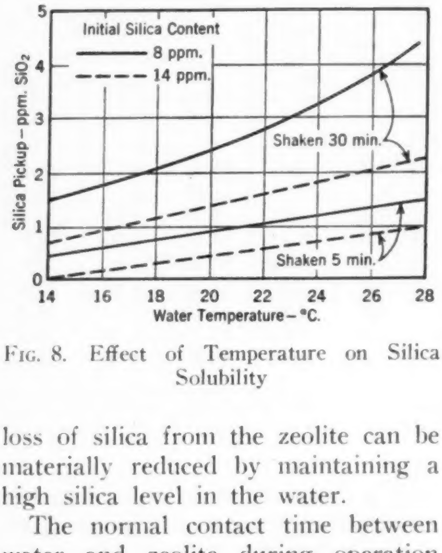

FIG. 8. Effect of Temperature on Silica Solubility

loss of silica from the zeolite can be materially reduced by maintaining a high silica level in the water.

The normal contact time between water and zeolite during operation varies between 3 and 5 minutes. Curves for the longer shaking intervals suggest that greatest economical protection for the zeolite is attained with Colorado River water at somewhere between 14 and 18 ppm. of SiO_2. Martin (9) found that silica losses were minimized for London water at 10°C. (50°F.) by increasing the silica content of the water to 13 ppm. It has been observed that the natural silica of waters held in surface reservoirs can be reduced to very low levels by the activities of diatoms. Whenever a water is low in silica, naturally or from other causes, the addition of silica to the water may be desirable.

If sodium silicate is added to the water to protect a zeolite, the manufacturers usually suggest maintaining silica levels high enough that the silica content of the zeolite effluent water is no greater than in the influent water. Silica pickup determinations by the ammonium molybdate method, which, according to Vail (17), is capable of detecting the soluble forms of silica, may, however, be meaningless in finding this saturation level. If grab samples are taken from the zeolite effluent water, the level found may be misleading because the rate of silica dissolution is not constant. The variation in silica content and pH of water samples taken during the course of a service cycle is shown graphically in Fig. 10. There is general agreement that the pH of the zeolite effluent water rises above the level of the influent water at the beginning of the softening run and the pH gradually drops as the run progresses. Other investigators (2, 12), however, have stated that silica losses followed the same trend as the pH change. Silica losses during operation with Colorado River water, with an influent level of 17.3 ppm. of SiO_2, pH of 7.5 and temperature of 74°F., have always increased as the softening run progressed, as shown in Fig. 10. This has been observed consistently with three different zeolites. The change may be due to swelling or hydration effects. The data emphasize the need for collecting a composite sample over a period of one or more softening cycles in order to obtain a reliable index of silica solubility.

Effects of pH

Zeolites are subject to more serious silica losses when waters of acidic or highly alkaline nature are treated. For this reason the manufacturers usually suggest pH control within the range of 6.8 to 8.0 (12, 14). Baker (13), comparing gel zeolites and greensands, found the former much more sensitive to attack by dilute carbonic acid solutions. In a more recent publication, Behrman and Gustafson state that (12), although operating exchange values were lowered, a gel zeolite did not deteriorate any more rapidly with a water held at pH 6.0 than at pH 7.8 during a prolonged test with Chicago water; but they present no supporting data. High pH waters cause swelling, softening and subsequent dissolution of the gel-type zeolites. Laboratory data for zeolites treated with Colorado River water held at pH 9.0 indicate that no greater immediate loss of silica occurred than at pH 8.0, the suggested upper limit. Undoubtedly an important reason for lowering the pH of highly alkaline waters is to prevent the precipitation of calcium carbonate in the pores of the zeolite. Wherever it is possible to control pH, limits of 6.8–8.0 should be observed.

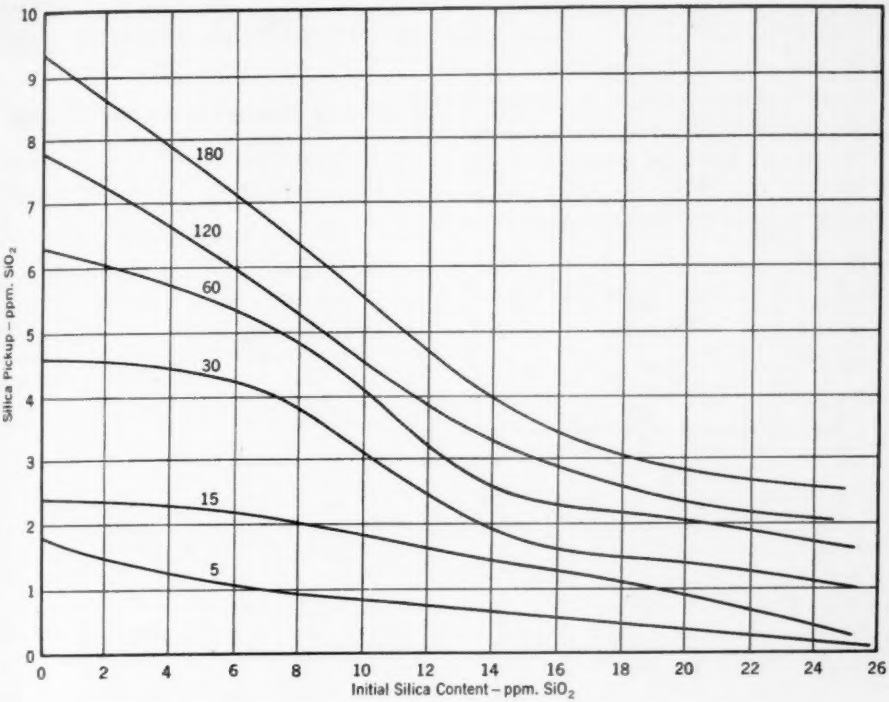

FIG. 9. Effect of Silica in Water on Pickup of Silica From Zeolite

Fluorides

Fluorides, when present in waters, may accelerate the dissolution of silica from zeolites by the formation of fluosilicates. Although the magnitude of this activity has not been investigated in the district laboratory, it has been

suggested (18) that somewhat higher silica levels must be maintained in a water containing appreciable amounts of fluorine in order to counteract the effect of the fluoride ion on silica solubility. Theoretically, 1 ppm. of fluorine is capable of reacting with about 0.5 ppm. of silica as SiO_2; thus, the presence of only 0.2–0.4 ppm. of fluorine would have a negligible effect, but larger amounts may have a greater influence on zeolite deterioration.

Salts in Water

If other more important factors, such as the temperature and silica content of the water, are held constant, it can be shown that silica solubility is increased as the total concentration of

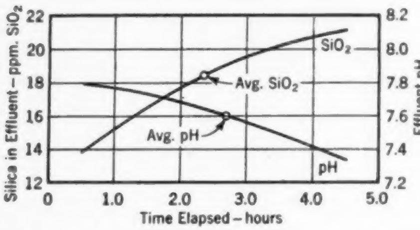

FIG. 10. Silica and pH Changes in Zeolite Effluent Water

dissolved salts in the water increases (Table 4). In addition, the type of salt present has an effect on silica solubility. Although Fig. 11 (water at 24°C.) does show how the effect of silica starvation obscures any differences in silica pickup from the zeolite by three kinds of water having the same cationic content but different acid radicals. As the silica content increased, the water containing sulfate and chloride ions caused greater silica losses than either the bicarbonate water or the water containing chloride, sulfate and bicarbonate ions together.

It has been suggested by Collins (2) that silica losses from a zeolite become greater as the mineral ages. Laboratory tests of several zeolites of various ages do not always confirm this observation, as shown in Table 5. The activity of bacteria which produce in their microsphere an environment richer in carbonic acid than in the surrounding water may create conditions favoring the dissolution of silica from old zeolites. The combination of a number of the factors discussed may account for an apparent increased aging rate for old zeolites.

Causes of Exchange Capacity Loss

The immediate effects of silica losses by dissolution from a zeolite are an in-

TABLE 4

*Effect of Soluble Salts on Silica Solubility From Zeolite**

Total Dissolved Solids	365 ppm.	730 ppm.
Shaking Time *min.*	Silica Pickup *ppm. SiO_2*	
5	0.0	0.4
30	0.3	0.9
60	1.6	2.5
120	2.0	3.1
180	2.3	3.5

* Initial silica in water, 18.0 ppm. SiO_2; water temperature, 24°C.

crease in porosity, a decrease in the apparent density or weight per cubic foot, and a decrease in the silica-alumina ratio. As channeling of the zeolite granules progresses, the resistance of the grains to attrition is reduced and they break down into finer sizes more rapidly. Within certain limits the increased channeling allows more rapid diffusion of ions through the gel structure, bringing more exchange surface into play and thereby compensating for the lost

weight of zeolite. As silica losses continue, the available exchange spots will be reduced, because the ultimate exchange value is based on the amount of zeolite present in pounds rather than the volume in cubic feet.

Data showing the weight per unit volume of several gel-type zeolites at different ages are presented in Tables 3 and 6. The three zeolites in Table 6 have been operated under identical conditions. The laboratory data illustrate the relative differences in resistance of the zeolites to aggressive attack under operating conditions.

lost exchange capacity as the weight per cu.ft. decreased, but in others the tendency toward greater porosity and finer grain sizes, with the resultant increases in exchange values discussed elsewhere in this report, has compensated for the change in weight per unit of volume of the materials.

The effect of silica losses on exchange capacity cannot always be explained on the physical basis already discussed; sometimes the change in exchange capacity may be related to chemical constitution and equilibrium dynamics. The apparent effects of

TABLE 5

*Effect of Zeolite Aging on Silica Solubility**

Zeolite	*J*			*K*		
Number of Regenerations	304	758	982	321	763	967
Shaking Time *min.*	Silica Pickup *ppm.* SiO_2					
30	1.7	1.7	1.9	1.5	3.4	3.5
60	2.5	3.0	2.7	2.7	4.2	5.5
120	3.3	3.4	3.4	3.5	5.6	6.3

* Initial silica, 15.3 ppm. SiO_2; water temperature, 24°C.

As the potential exchange capacity of a zeolite containing 10 per cent of Na_2O is equivalent to about 1,000 grains of $CaCO_3$ per pound of oven-dry material, a maximum exchange value of about 30,000 grains of $CaCO_3$ per cu.ft. of synthetic zeolites is theoretically possible. If the surface reaction of new material weighing 30 lb. per cu.ft. gives an exchange value of 9,000 grains per cu.ft., a loss of silica which reduces the weight of mineral to a value of 20 lb. per cu.ft. should cause some loss of exchange capacity expressed on a volume basis. Some of the zeolites shown in Table 3 have

chemical changes, but not the latter subject, will be discussed. It seems that a zeolite with an initially high $SiO_2:Al_2O_3$ ratio is likely to show a loss of exchange capacity as this ratio drops below 4.0:1. Zeolites D and E in Table 3 illustrate this point. Collins (2) showed an extreme loss of operating exchange for a zeolite with an initial $SiO_2:Al_2O_3$ ratio of 9.6:1 and a final ratio of 3.87:1. Several zeolites made in Europe (7) and a few made in this country may have an initial silica-alumina ratio as low as 3.0:1. Such materials do not have an appreciable silica reserve, and their

use should be limited to relatively non-aggressive waters. In the authors' opinion, the use of minerals with SiO_2 : Al_2O_3 ratios as high as 13 : 1 will not reduce the rate of silica dissolution, but may merely postpone the time at which physical and chemical destruction of the gel finally occurs. As the silica continues to decrease, the alumi-

ging effect such as that observed with iron-bearing waters.

The fouling of synthetic zeolites by various organic materials, colloidal clay, iron, manganese, calcium carbonate and bacterial slimes, has often been observed. The surface clogging of pores in the grains of zeolite can be prevented by removing these contami-

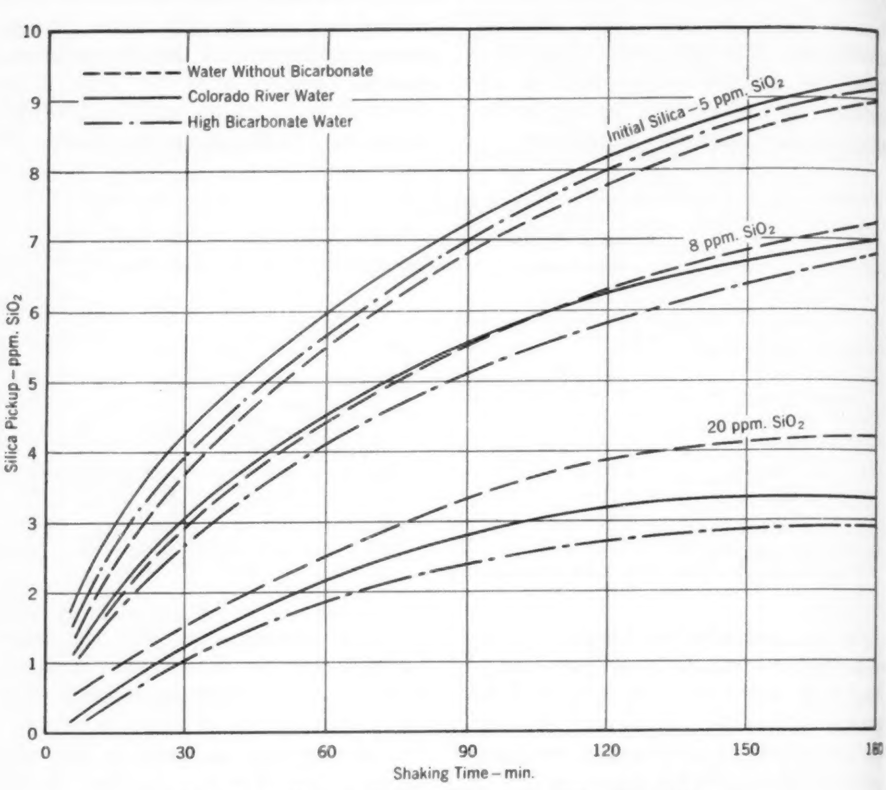

FIG. 11. Effect of Water Quality on Silica Solubility

num content of the gel will increase, but it is probable that not all of the alumina remaining after much silica has been removed from the gel will be an active part of the zeolite structure (1, 19). Some alumina may, instead, tie up exchange spots or precipitate in the exchanger pores, causing a clog-

nating substances from the water before zeolite treatment. When iron is present in amounts greater than 1.0 ppm. it may cause a loss of exchange capacity after long service. Manganese reacts in a similar fashion. The removal of iron and manganese by precipitation and filtration before sof-

tening is advisable to prolong the life of the synthetic zeolites. If greensands are used, however, both iron and manganese may be removed from waters by an exchange process employing other regeneration procedures (20). The need for lower pH values as a control of calcium carbonate incrustation and the effects of suspended matter have been discussed previously. Bacterial slimes frequently interfere with zeolite activity affecting the exchange capacity and fostering a more rapid chemical deterioration of the mineral. Controlling the growth of micro-organisms by either intermittent heavy chlorination or regular chlorination will be beneficial in prolonging the life and exchange capacity of the zeolite.

TABLE 6

Changes in Apparent Density of Zeolite During Aging

Zeolite	*M*	*N*	*O*
No. of Regenerations	*lb. wt. per cu.ft.*		
0 (New)	28.9	27.0	28.9
315	25.4	23.1	—
775	25.2	21.5	23.5
1000	24.2	20.8	23.7
2600	—	18.4	—
3080	—	17.9	—

Revivification of Zeolite

Manufacturers of zeolite have evolved procedures intended to restore to a mineral a high proportion of the exchange capacity lost after prolonged use. The recommended procedures vary from a simple cleansing of the minerals by means of dilute acid or dilute caustic solutions, depending on the nature of the material suspected of coating or plugging the zeolite grains, to more complicated, multiple-step techniques intended to restore to the zeolite some of the silica lost by dissolution. Among the procedures suggested are:

1. Cleansing with acetic acid.
2. Treatment in successive steps with three applications of brine, followed by contact with solutions of sodium hydroxide, sodium silicate, and finally alum.
3. Treatment with ammonium sulfate solution.
4. Intermittent high-dosage chlorination to remove bacterial slimes.

One or another of these procedures may achieve the desired purpose, and the manufacturer of the mineral is generally best qualified to recommend the revivification process to be tried on his product.

Occasionally it was found that, if none of the methods mentioned were successful in revivifying an old mineral, screening to remove fines smaller than No. 50 U.S. Std. Sieve Series, and subsequent crushing and screening of the remaining material to select particles of a size passing No. 16 and retained on No. 50, have yielded a product having a greatly improved exchange capacity and salt economy. The amount of usable zeolite recovered following this processing will depend upon the degree of crushing necessary to produce the desired exchange capacity. The capacity and salt requirements of the crushed mineral compare favorably with the characteristics exhibited by some new zeolites. The improvement achieved by crushing may be attributed to the availability of new exchange spots on the freshly exposed surfaces of the mineral.

Operating Procedures

The rate at which a zeolite softener unit can be operated depends on whether the operation is downflow or upflow. Theoretically, the maximum rate of downflow operation would be limited only by the need for a certain minimum contact time between water and zeolite to effect the base-exchange reaction. The reaction rate would depend on the type of zeolite and the size and porosity of the granules. In practice, the downflow rates usually recommended by the manufacturers approximate 3 gpm. per sq.ft.

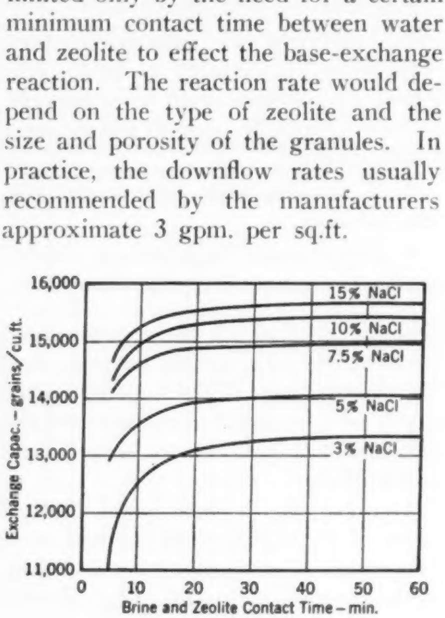

FIG. 12. Effect of Brine Concentration and Contact Time on Exchange Capacity

Permissible upflow rates are subject to all of the factors enumerated above. In addition, the density of the zeolite would necessarily be of primary importance to its expansion and the possibility of mineral loss by carryover. The distance from the top of the zeolite to the top of the overflow troughs should be sufficient to permit at least 100 per cent expansion. The district softener units are of the upflow type and were designed to be operated between the rates of 5 and 8 gpm. per sq.ft. In actual operation, even at the maximum softening rate of 8 gpm. per sq.ft., the expansion of any zeolite which has not been reprocessed seldom exceeds 30 per cent.

The regeneration procedure is the most vital part of zeolite operation. Insufficient salt, insufficient contact time, insufficient rinse water, or improper brine concentration can produce poor softener operation. Although 0.17 lb. of salt is theoretically required per kilograin of hardness removed, two to three times this dosage is usually required in operation to obtain efficient exchange. It has been found that:

1. Within certain limits, variation of the concentration of brine has little effect on the efficiency of the regeneration process. For a relatively new mineral, these limits of concentration are shown (Fig. 12) to lie between 7 and 15 per cent of sodium chloride.

2. Enough brine must be used in regeneration to more than fill all the voids between the zeolite grains.

3. The movement of the brine through the softener should be continuous and at such a rate that all the liquid may come in contact with the zeolite granules and not slip by (1).

4. The contact time between brine and zeolite should be long enough to

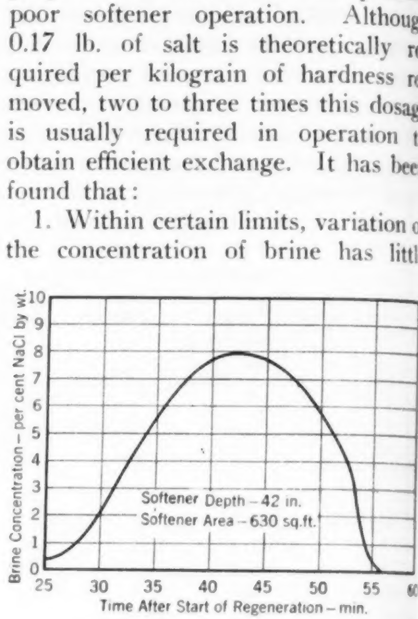

FIG. 13. Waste Brine Concentration During Regeneration

permit maximum regeneration of the mineral. Reference to the test illustrated by Fig. 12, for which salt dosage and temperature were kept uniform, shows that the contact time with the brine should be at least 20 minutes if high regeneration efficiency is to be attained.

In plant operation it is rarely possible to put all of the brine through the softener at a specific concentration. In district softener operation it has been found desirable to apply the brine

TABLE 7

Data for Softening Run Shown in Fig. 13

	Time After Start of Regeneration *min.*
Slow drain open	1
Dilute brine start	2
Dilute brine end	7
Rinse water start	17
Rinse water end	53
Fast drain start	53
Drain close	58

	Rate *gpm./sq.ft.*	Quantity *gal.*
Saturated brine	1.08	2,880
Dilution water	0.51	1,700
Rinse water	1.47	33,000
Slow drain	0.76	—
Fast drain	6.60	—

as rapidly as possible to the top of the zeolite so that the major portion of the brine brought in contact with the mineral will have, after dilution in the bed, a concentration higher than 4.0 per cent NaCl. The typical curve in Fig. 13 illustrates the data derived from analyses of spent brine sampled throughout the regeneration of the district softener units. Curves of this type have proved very useful in establishing regeneration procedures for maximum efficiency in zeolite operation. The fresh water rinse following the brine is applied in such a manner as to reduce dilution of the brine to a minimum. It must, of necessity, pass through the zeolite at the same rate as the brine until the concentration of the brine leaving the bed is less than 4 per cent NaCl, after which the rinse is increased to the full capacity of the fittings. Generally, the quantity of rinse water required depends on the concentration of chlorides permitted in the water at the start of the softening run. This may vary with the particular requirements of the user of the softened water. The data for the run are given in Table 7.

Summary

The operating exchange capacity of a synthetic siliceous zeolite is influenced by the chemical composition, grain size and porosity of the mineral; by the depth of zeolite in the softener unit and the rate of softening; by the degree of exhaustion to which the bed is run; by the quality of the water being softened; and by the salt dosage and regeneration procedures used. Of particular importance to the exchange capacity of a zeolite is the salt dosage.

Life expectancy of zeolites is a function of the chemical and physical characteristics of the different minerals and of water quality, particularly silica content and temperature. Although control over water temperature is usually not feasible, silica content can be increased, pH can be adjusted, and soluble and insoluble impurities can be controlled to prolong zeolite life.

One of several revivification processes may help to restore to an old zeolite some of the operating exchange capacity lost after prolonged use.

Proper control of brine concentration and contact time between brine

and zeolite during regeneration is essential if optimum exchange capacity and salt economy in zeolite operation are to be attained.

Acknowledgments

The authors wish to acknowledge the co-operation received from Charles P. Hoover and J. M. Montgomery, Cons. Engrs.; H. M. Olson of the Ohio Salt Co.; John W. Krause of La Grange, Ill.; Walter W. Graf and W. D. Deeds of Lancaster, Ohio; L. F. Cook of Cuyahoga Falls, Ohio; Harry Kerr and J. A. Haeberle of New Philadelphia, Ohio; M. E. Gilwood of the Permutit Co.; H. B. Gustafson of Infilco, Inc.; F. K. Lindsay of the National Aluminate Corp.; the laboratory staff of the district; and others in the professional field who have contributed ideas and data to these investigations.

The Metropolitan Water Dist. operation is under the direction of Julian Hinds, General Manager and Chief Engr. The Chief Operations and Maintenance Engr. is Robert B. Diemer. These research investigations and the water softening and filtration plant are under the direct supervision of William W. Aultman, Water Purification Engr.

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Discussion

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It is fortunate for those who are interested in base exchangers that the Metropolitan Water Dist. of Southern California had an investment in synthetic zeolite installation so considerable as to warrant research to safeguard that investment. The studies of these researchers have brought forward a body of new knowldge, and thanks are due to them for those original contributions as well as for bringing into available form the previous work of others.

Of particular value is their emphasis upon the observation that if two exchangers are to be compared, it is essential that the particle sizes be the same. In the same vein it is evident that specifications for the purchase of exchangers will be of little value unless the exchange capacity is correlated with the salt consumption per unit weight or volume of the exchangers.

Although some practical knowledge existed heretofore of the causes for the deterioration of exchangers accompanied by loss in exchange capacity, the authors have brought forth convincing evidence of the paramount importance of the loss of silica as contributing fundamentally to loss in values. Their suggestion of partial remedies also affords some hope.

Although largely empirical, the studies do canvass some of the chemical factors which may affect the behavior of certain exchangers, and allude to the probable effect of equilibrium dynamics. It seems probable that the key to much that is still hazy in exchange reactions may be found in equilibrium dynamics, and it is fair to hope that some of the authors' future studies may explore this area.

The complexity of the problem surrounding the probable life of zeolites fully underscores the reason why accelerated tests for the determination of the life of exchangers are still in controversy; although the routine tests for the determination of exchange capacity and other characteristics are so generally employed as soon to warrant their adoption as accepted standard methods.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research* (*British*).

WATER WORKS ANNUAL REPORTS

11th Annual Report (1946) Little Rock (Ark.) Munic. Water Works. Three-man board. Pop. of city, 105,000; pop. served, 132,400. Per capita production 80 gpd.; sales 67 gpd.; 22,622 customers. Income, $853,017. Fixed assets of $8,110,582 and cash reserve of $924,655 offset by capital liabilities and funded reserves of $6,244,086. Surface water supply, watershed 43 sq.mi., normal rainfall 48″, normal run-off 14 bil.gal., impounding reservoir 14 bil.gal. A 39″ pipeline 35 mi. long, capac. 25 mgd., delivers water to 92-mil.gal. auxiliary storage reservoir and 15-mgd. filtration plant. Water production avgd. 11.15 mgd., max. 15.55 mgd. Total hardness of water delivered, 33 ppm. Elec. pumping station rated capac. 14.25 mgd. Distr. system: 142 mi. of 4″–24″ mains and 130 mi. of 1″–3″ mains deliver water to 1108 hydrants and 22,034 meters. Planned improvements in distr. system well under way. Use of free residual chlorination to restore capac. of supply main very successful. Some refuse still clings to pipe and must be removed mechanically to restore capac. fully. Constr. of chlorination bldg. separate from filter bldg. under way. Reinforcement of distr. system by 6 mi. of 12″–24″ mains costing $530,000 practically completed. Total main constr., 22.6 mi.—*O. R. Elting.*

1946 Annual Report, Denver (Colo.). Pop. 423,000. Water consumption avgd. 79.97 mgd. Income, $3,537,197; disbursement, operation and maint., 30%; depn., 18%; capital expense, 41%; invested capital, 11%. First cost of plant, $44,506,279; cash investment, $3,813,000. Capital liabilities, $20,701,000. Total services 86,839; active meters 4042, 3431 services added. System consists of 115 mi. of 12″–84″ conduits and 861 mi. of 1″–48″ mains in distr. system. 4575 fire hydrants. Source of supply, South Platte R. 50%, Fraser R. 28%, storage 18%, Cherry and Bear Creeks 4%. Filter plants and pumping stations 176 mgd. capac. Distributing res. 99 mil.gal., operating res. 10,686 mil.gal., storage res. 63,397 mil.gal. Highest consumption on record Aug. 8, 177.94 mgd. War gardens became peace gardens in '46, 3976 permits issued. Financing of improvements costing $30,000,000 will be 25% by anticipated surplus and 75% by bonds to be authorized.—*O. R. Elting.*

47th Annual Report (For Year Ending Mar. 1947), Dubuque (Iowa) Water Dept. City mgr. with mayor and council. 8 artesian wells 1300′ to 1781′ deep, 6″–16″ diam., and mine tunnel. Pump capac. 35 mgd., storage 11.7 mil.gal., 121 mi. mains, 927 hydrants, 10,046 services (100% metered). Pop. '40, 43,892, consumption 3.41 mgd. Depreciated value of plant $1,685,420, investment $215,000. No bonded debt. Revenue $202,486, operation and maint. $112,834, main extensions $28,513, other betterments $72,251, transferred to city $15,000; total $228,598. 72% water salable. Recommended improvements: softening plant $350,000; 1.5-mil.gal. storage reservoir, $67,500; 24″ feeder main, $17,500; 12″ feeder main, $24,000; warehouse and repair shop, $40,000; pumping unit, $3500. No tax levy or hydrant rental. 25% of salaries of city mgr., auditor and treasurer paid from water funds.—*O. R. Elting.*

1946 Annual Report, Louisville (Ky.). Company owned by city and operated by board. Estd. pop., 375,000. Ohio R. water pumped to reservoir and repumped after purif. Consumption 56.94 mgd.; 765 mi. of mains; 78,786 services, 100% metered; 3745 hydrants. Operating income $0.0706, expense $0.06411 per 1000 gal. Revenue $2,788,540, net profit $1,393,984; fixed capital $24,067,-949. Funded debt $404,000 due '50. Funds to balance total requirement for retirement of issue voted from current funds and $300,000 for improvements and expansion. Company in fact debt free. In '46 new coagulation basins and water softening equip. placed in operation. Softening limited by lack of chems.; 60" force main from river to reservoir proved its value. Electrification of pumping station not completed. Employees of company, exclusive of office force, formed union affiliated with CIO. North Res. cleaned, 30,000 cu.yds. removed; cost $4019, last cleaning '42. 51 breaks in distr. system, 14 in Dec. Filtered water storage 57 mil.gal. Pump capac. 230 mgd. raw water, 152 mgd. filtered water.—*O. R. Elting.*

Cadillac (Mich.) Report (For First 11 Months of Municipal Operation of the Water Dept., Ending June 30, 1947). System purchased (cost $300,000) by issue of revenue bonds maturing '48 to '67; interest rate 1.25%. Operating income $69,495, premium and interest on bonds $760, operating expense $28,414. Payment in lieu of taxes, interest, depn. and services retired, $14,303. Net income: bonds $8408, depn. $1500, interest $375, surplus $17,255; total $27,538. Customers 2494; 335 metered. Pumpage, 1.709 mgd. Revenue $121.75; operating expense $49.78; taxes, interest and depn., $23.07; net income $48.90 per mil.gal. New chlorinator permitting free residual chlorination greatly improved qual. of water and insures perfectly safe water.—*O. R. Elting.*

94th Annual Report (For Year Ending June 30, 1946) Dept. of Water Supply, Detroit (Mich.). Four-man Board of Water Comrs. Pop. 2,300,000; 441,966 services (99% metered)—increase of 4567. 28,721 hydrants in city of Detroit only. Water supply Detroit R. direct pressure (except for 6 elevated tanks with total capac. of 9.5 mil.-gal.), through 5208 mi. of mains by 3 pumping stations with total capac. of 1188 mgd. Two rapid sand filter plants with total rated capac. of 592 mgd. Gross revenue $8,879,687 or $3.86 per capita, $26.97 per acct., $1746 per mi. of main, $80.76 per mil.gal. Operating and maint. expense of $3,741,840 or $34.03 per mil.gal. Capital expense $4,596,305. Net cost of works $129,884,747, bonded debt $58,615,000; value of sinking fund $18,857,-260; interest rate 4.10%. Income and expense per 1000 cu.ft. (revenue water basis): revenue $0.728, operating and maint. $0.307, fixed charges $0.377, net income $0.044. Pumpage avg. 301.22 mgd., max. 431.62 mgd., min. 123.12 mgd. Avg. consumption 131 gpd. per capita or 677 gpd. per service. Salaried employees 550; per diem employees 595. Cost of operation and maint. of 20-story water board bldg. $1.24 per sq.ft. of rentable area. Water board occupies 7 floors, remainder occupied by various city depts. Sewage disposal system operated under board's jurisdiction. Decrease of 7% in pumpage due to reconversion problems in industry and strikes. Virtually no complaints of low pressure. Contracts let for 33,616 ft. of 54", 48" and 36" mains. Chlorination procedure changed due to presence in raw water of phenols from synthetic-rubber plants.—*O. R. Elting.*

Elmira (N.Y.) Water Board Report (1946). Municipally owned since '15. Elected board of 5 men, overlapping terms. Pop. 65,000; 6.386 mgd.; 153 mi. mains 4" and larger; 839 hydrants; 15,287 services, 100% metered. Plant first cost $2,914,946; depn. $912,395; cash, investments and special fund reserves $279,900; debt free. Income $300,335; operating costs, including taxes and depn. $207,-876. Supply: Hoffman Creek (31%), gravity; Chemung R. (69%), pumped. Purif. plant of 24 rapid sand filters. Reservoir capac. on distr. system total 6.5 mil.gal. Flood of May 28 put pump station and Chemung R. supply out of service for 4½ days. Repair and damage cost $7007. Cleaning up of city following flood raised consumption from normal 6 mgd. to 12 mgd. for 3 days.—*O. R. Elting.*

Aberdeen (Wash.) Water Dept. (6-mo. Financial Report Ending June 30, 1947). Gross income $123,983; operating expense $82,379; miscellaneous revenue $6097; operating income $47,701; interest, taxes, etc. $26,615; profit $26,623. Assets: fixed $3,149,-584; investments $143,829; other $277,629; total $3,571,042. Liabilities: bonds $698,000, special munic. tax revenue $432,950; current $37,504; reserves $1,135,947; surplus $1,266,-642.—*O. R. Elting.*

1946 Annual Report, Water Dept., Seattle (Wash.). Estd. pop. served 548,227. Estd. consumption 75.75 mgd. Peak 158.4 mgd. Water mains total 1182 mi. serving 108,495 metered services and 10,707 hydrants. In '46, 15.6 mi. of mains, 211 hydrants, 3955 services added. Gross operating revenue $3,381,525; non-operating revenue $74,124; operating expense $832,254; depreciation $694,654; interest on bonds $138,303; amortization of franchise $600; taxes $1,057,-492 leaving net income $732,345 added to surplus acct.: total surplus $14,521,480. Depreciated net value of resources $23,904,-487. Outstanding bonds $3,067,000. Cost of water delivered per mil.gal.: operation, maint. and depreciation $55.40; total $98.49. Tap water, total hardness 23.9 ppm.; pH 7.2; Cl 2.7 ppm. Avg. employees 283 as against 207 in '45. Sick leave avgd. 1.7%. Increased cost of water delivered due to higher material cost and increased labor cost and manpower. 2228 acres of watershed acquired, looking toward acquirement of entire watershed. Report made setting up guide for major development for supply equiv. to 86% in excess of present demand.—*O. R. Elting.*

Milwaukee (Wis.) Annual Report (1946). Report of all city activities. Water works total revenues $3,564,081; operation cost including depn. and taxes $2,771,403. Value of plant $35,364,138; bonded debt $1,400,000; city's proprietary interest $30,629,531. Pop. served 700,000. Avg. consumption 147.2 gpd. per capita, 1000 mi. distr. mains.—*O. R. Elting.*

Chatham (Ont.) Annual Report, 1946. W.W. Inf. Exch.—Can. Sec. A.W.W.A. **6**:E:23:40 (Mar. '47). Pop. 22,700. Supply from Thames R., filtered and treated with Cl and $(NH_4)_2SO_4$. Consumption: max. 6.278 mgd., avg. 3.428, per capita 152 gpd. Unaccounted-for water 12.7%. Cost of water 6.35¢ per 1000 gal.; revenue 14.8¢. Assets $983,602.52, receipts $124,581.66, disbursements $113,074.52. Rate schedule in ¢ per 1000 gal. (net): domestic 28, schools and hotels 18, railways 10, mfg. 10–12.25.—*R. E. Thompson.*

Kitchener (Ont.) Annual Report, 1946. W.W. Inf. Exch.—Can. Sec. A.W.W.A. **6**:E:24:42 (Mar. '47). Pop. 39,150. Source wells. Avg. consumption 4.361 mgd., 111 gpd. per capita (8079 of 8086 services metered). Revenue $144,682.56, expenditures $85,999.40, balance after depn., etc., $27,-518.04, total surplus to date from earnings $374,750.29, assets $2,003,715.24.—*R. E. Thompson.*

The Water Works of the City of Bombay. Wtr. & Wtr. Eng. (Br.) **50**:201 ('47) Admin. report of Bombay Waterworks Dept. for '45–'46 states that all areas of city, except certain elevated parts, supplied with water by gravitation from Tansa, Vehar, and Tulsi Lakes. Water sterilized by chlorine treatment. Maint. work included about 290 sq.ft. of patch plates welded to steel mains. New works proposed are outlets at different levels at Tansa dam and laying of 2 steel mains. Flash boards provided on waste weir of Tansa dam to catch monsoon of '45. Balancing reservoir of 275 mil.gal. (Imp.) capac. to utilize tail waters of Bhivpuri power station has been approved.—*H. E. Babbitt.*

The Baghdad District (Iraq) Water Board (Year Ending Mar. 31, 1945). Wtr. & Wtr. Eng. (Br.) **49**:227 ('46). Some 2000 were on waiting list at end of year for connection to water supply. Minor alleviations resorted to for some. In June '44 priority granted for filtration plant and pressure mains to increase capac. of Sarrafiya works. Water supply of Baghdad pumped from Tigris R. at 4 stations. Layout of mains dets. dists. which may be switched from one supply area to another. Total quant. pumped during year 12,544,000 cu.m. Demand for garden water as pressing as for drinking water. Leakage showed normal increase over previous year. Main extensions totalled 4227 m., bringing total length to 378.7 km. In 98.5% of samples collected, *Esch. coli* absent from 100 ml., and avg. colony count on all samples 23. Water considered excellent. Filtration and chlorination resulted in 700-fold reduction in bacteria.—*H. E. Babbitt.*

Water Supply of the City of Auckland, New Zealand. Wtr. & Wtr. Eng. **49**:677 ('46). Annual report for yr. ending Mar. 31, '46 shows total quantity supplied was 5840 mil.-gal. (Imp. gal. are used throughout), and increase of 473 mil.gal. over previous yr. Storage in reservoirs, when full, equaled 1569 mil.gal. During 4 mo. of yr. there was only 4.28″ rainfall as compared with long-period avg. of 13.5″ for these months. Necessary to apply restrictions for remainder of summer

season. Extension of Nihotupu dam continued together with erection of pumping station and laying of 24″ main. Contract let for constr. of 6 mil.gal. concrete reservoir on Mt. Albert. Further works performed include reticulation of new residential subdivisions and commencement of laying of new feeder main in commercial area. Preliminary investigations, designs and estimates completed for new headworks at Lower Huia and Cossey's Creek, Hunua. Total length of new mains laid during yr. over 14 mi. Total length of all mains is now 555 mi.—*H. E. Babbitt.*

TREATMENT—GENERAL

Compression Distillation of Sea Water. ROBERT G. SKERRETT. Compressed Air, **51**:123 (May '46). One of the best kept wartime secrets was how we were able to furnish our fighting men with fresh water, especially in regions such as Pacific islands where rainfall at unpredictable times offered only supply. More efficient method for doing this devised by Dr. Robert V. Kleinschmidt, who has developed unit based upon compression-distn. principle for Navy. First model placed in production for shipboard use in Mar. '41. Effectiveness made unit desirable to both Army and Marines, who desired portable models driven by internal combustion engines instead of by elec. motors. Unit dists. sea water in following steps: App. and its contents are first brought up to operating temp. by period of heating. When evaporator filled with steam, still may be turned 'on stream' for continuous operation. Sea water first heated upon entry by passing through triple-passage, liq.-to-liq. heat exchanger. Outgoing distillate and brine used to heat incoming water to temp. of about 207°F. Feed then enters evaporator, where it mixes in relatively large vol. of brine. Steam from evaporator then compressed, raising pressure about 3 psi. gage, thus advancing its satn. temp. to about 222°F. Brine in evaporator boils at about 213°F. This permits transfer of heat from compressed steam to boiling brine, since there is temp. differential of 9°F. All latent heat of compressed steam used in maintg. evapn. in evapn. space. Unit having capac. of 1000 gpd. requires about 20 w. of current to produce 1 lb. of distillate, as compared with 300 w. for single effect evaporator. Latest compression stills in service avg. at least 175 lb. of distillate per lb. of fuel consumed.—*P.H.E.A.*

Sea Water Fractionator. WILLIAM F. BORGERD & JOHN S. PALMER. U.S. 2,419,881 (Apr. 29, '47). App. designed for prepn. of potable water through freezing procedure. Crystals strained from mother liquor and melted by heat from refrigerating machine used to supply necessary low temp. Structural details given.—*C.A.*

Military Water Distillation Equipment. C. M. PARKIN JR. Military Engr. **38**:468 (Nov. '46). Large quants. of potable water necessary in many areas during World War II where it could be obtained only by distn. Single effect unit first developed. It was indirect-fired in that heat for evapg. sea water supplied by steam generated in fresh water boiler. It produced 50 gph. of distd. water with water to fuel ratio by wt. of 12 to 1. Single-effect equip. superseded by direct-fired double-effect equip. Ferrous metals used throughout to conserve more corrosion-resisting materials because utility life of military equip. much less than obsolescent life. Two double-effect units with capacs. of 2000 gpd. and of 5000 gpd. designed. They produced 24 lb. of distd. water per pound of fuel. Triple-effect distn. unit of lighter wt. next designed. It produced 2500 gpd. at rate of 36 lb. of distd. water per pound of fuel. This unit could also be used to heat water for bathing, as source of low pressure steam, to furnish heat to disinfest clothing, and to boil fresh water to destroy disease organisms that are resistant to normal methods of water purif. Thermocompression distn. equip. next designed. It operated on compression cycle. Steam compressed to raise its temp. and pressure, and as this steam was condensed it evapd. more sea water that passed through same compression cycle. It had continuous feed and blow-down. Units designed with capacs. of 1200, 3000 and 6000 gpd. Operating economy, in pounds of distd. water per pound of fuel used by power unit, ranged from 175 for gasoline-driven units to over 200 for larger (6000-gpd.) diesel-driven units. Equip. has since been developed that can produce 250 lb. of distd. water per pound of fuel, and data have been obtained to design 25,000-gpd. unit for postwar garrison use.—*P.H.E.A.*

A Surface Water Treatment System for the Rural Home. Joe B. Winston. Bul., Agric. & Mech. College Texas. **1**:89, 42 pp. (Dec. 1, '45). This bulletin presents constr., installation, operation, and maint. details for slow sand filter plant applicable to treatment of surface waters for individual family use in rural areas. Disinfection of filtered water by daily dosing in storage tank with hypochlorite required as essential part of treatment. Plant consists of raw water intake line, slow sand filter, and filtered water storage tank. Reinforced concrete pipe sections with poured concrete bottoms suggested as suitable for constr. of filter and storage tanks; tables as to capacs. and instructions for assembly given. Filter has underdrain made of one length of 2″ pipe, having 2 rows of ¼″ holes, drilled 1½″ apart on lower side, 45° to left and right of the vertical; 6″ depth of "pea" or "roofing gravel"; and 12″ of "builder's sand" over gravel. Outlet riser pipe from filter underdrain to filtered water storage tank set so that 2″ head provided on filter unit. Avg. rate of filtration 50 gal./sq.ft. of filter area per day, equiv. to rate of approx. 2 mil.gal./acre daily. Filtered water storage tank has capac. equal to 2 days' water requirements. Raw water flow to filter controlled by float valve on raw water inlet line with actuating float located in filter unit. Instructions given for disinfection of filter and storage tank contents in starting system. Thereafter indicated that residual chlorine test be made (using o-t.) on water in storage tank each morning and that hypochlorite be added if necessary, so that canary-yellow color obtained in subsequent chlorine tests. Table shows amt. of chlorine soln. to be added daily to storage tank if no o-t. test kit available. This table provides for treatment of entire contents of storage tank at chlorine dose of 3 ppm.—*P.H.E.A.*

Water Treating for Secondary Recovery. Paul De Lozier. Oil Weekly, **125**:13:53 ('47). Discussion of chem. treatment of water to be used for secondary recovery of oil from oil sands, in order to prevent troubles from corr. or deposition of scale in pipelines or sand.—*C.A.*

Activation of Oxygen by Ultrasonic Radiation. J. Loiseleur. Compt. rend. Acad. Sci. (Fr.) **218**:876 ('44). When water exposed to action of ultrasonic waves, dissolved gases liberated; this phenomenon known as cavitation and accompanied by activation of oxygen molecule. This may be demonstrated by production of hydrogen peroxide in distd. water which is exposed to ultrasonic waves produced by vibrating quartz and by effect of ultrasonic radiation on reagents which change color on oxidation.—*W.P.R.*

DISTRIBUTION SYSTEMS

Tisdale Township (Sask.) Winter Hydrant Inspection Method Checks Leaks. C. S. Anderson. Eng. Cont. Rec. (Can.) **60**:3:90 (Mar. '47). With winter temp. as low as −50°F., difficulty experienced due to freezing of hydrant stems and caps. Careful inspection in fall and application of Prestone anti-freeze to packing and caps aid materially. If weekly inspection discloses leakage, hydrant flushed, pumped out and reinspected following day, repairs being made if leakage persists. When ground water enters through drain holes, latter plugged. Frost casings driven down each spring. Frozen hydrants thawed with small portable steam unit heated by gasoline torch.—*R. E. Thompson.*

Artificial Increase in Oxygen Content of Water in Mains. R. Meulenhoff. Water (Neth.) **31**:55 ('47). New water system constructed in '35–'36 carries water from 6.5 to 8.2 mi. before it is delivered to consumer. After few months in operation taste and odor troubles appeared, esp. at dead ends. Chem. anals. showed low D.O. and considerable org. matter. Anaerobic decompn. resulted in taste and odor. Extensive and daily flushing reduced complaints of odor, but turbidity of water increased materially. Daily flushing continued for 2 years, but not possible to obtain more than traces of oxygen in part of system. Expts. with compressed oxygen gas fed directly through elbow contg. thin mat of wood fiber to prevent large bubbles from entering into main, showed possibilities. Installation erected consisting of boiler filled with oxygen into which water was sprayed and oxygen-satd. water dischgd. into loop of system rather than in main. If installation connected with main, resistance would be too great in case of fire. Boiler placed parallel with water line. Filling of boiler with oxygen direct from hand-operated oxygen cylinders. Only part of applied oxygen reaches dead

ends, but difficulties disappeared. Quants. of oxygen supplied varied with temp. of water. Amt. of water wasted by flushing reduced by about 65%.—*W. Rudolfs.*

Design of First Flexible Pipe Joint Resulted From Study of Lobster's Tail. M. N. Baker. Eng. News-Rec., **136**:722 (May 2, '46). First water main with flexible joints designed by James Watt and laid beneath the River Clyde at Glasgow, Scotland, in 1810. Pipe consisted of 15″ inside diam. heavy cast-iron (1″ thick) segments 9′ long, with every other joint a portion of a sphere, the other joints being spigot or slip joints. Pipes held together by frames of 2 parallel logs; frames joined together by strong cast-iron hinges. Frames and hinges designed to permit motion only in vertical plane, permitting flexibility needed to meet irregularities of river bed. Pipe and frame covered in trench dredged across river. Addnl. stability obtained by driving row of piles adjacent to pipe on downstream side, cut off a little above top of pipe.—*P.H.E.A.*

Cleaning of Mains. W. L. Boerendans. Water (Neth.) **31**:1, 11 ('47). Lab. exptl. results obtained with various types of cleaning devices, including elongated ball with bristles, on the side, round ball with bristles, round ball with mussel shells, and thimble-shaped device, showed that with a round ball and mussel shells pushed forward at veloc. of 0.16 m./sec. good cleaning obtained. In practice cleaning of 12″ line through which water flowed normally at rate of 0.70 m./sec. was accomplished with round wooden ball (270 mm. diam.) and mussel shells when avg. veloc. of water passing ball was 0.85 m./sec. and veloc. along wall of pipe was 1.055 m./sec. Length of pipe was 2200 m. (7216 ft.). Calcns. showed that crust of manganese in pipe was 7.5 mm. thick. Another test in raw water line 8092 m. long (30,921 ft.) where inside walls covered with fresh water mussels (*Dreissensia polymorpha*). Wooden ball crushed considerable portion of mussels, but cleaning not complete. To prevent further growth, chlorination practiced. After few years, corrosion tubercles began to develop and some org. material retained between tubercles. Tests made by introducing sand and wooden ball. Org. material dislodged. When ball reached double syphon under river difficulties encountered; sand settled, ball stuck, etc. Various other types of devices constructed and eventually steel cylinder with inside diam. of 760 mm., covered with removable steel brushes, constructed in such a way that it could be dismantled in line when it got stuck. Two balls in tandem used, connected by steel cable. Resistance had increased 135%; cleaning recovered 60% each year. Cleaning accomplished while line in use.—*Willem Rudolfs.*

Cleaning of Water Mains. P. W. J. M. Driessen. Water (Neth.) **31**:84 ('47). Cleaning of 12″ 8200 m (26,900′) pressure main after 40 yr. of use without interruption of service. Cleaning accomplished by rotary scraper. Amt. of iron removed 180 tons dry wt., or 4.7 kg. per sq.m. pipe surface. Friction coefficient, according to formula: $I = a \frac{Q^2}{D^5} L$, where a is friction coefficient, 0.0045 before cleaning and 0.0025 after cleaning. Eight yr. later coefficient increased to 0.0036 and pipes again cleaned.—*W. Rudolfs.*

Rock Island Restores Pipe Line Capacities with Acid Solvents. Anon. Ry. Eng. & Maint. **43**:587 (1947). Chicago, Rock Island and Pacific Ry. has experienced considerable success during past few years in cleaning a number of badly incrusted pipelines from 8 to 12″ in diam. and from 400 to 1200′ long, with acids, using an inhibitor to prevent damage to pipe and fittings. After character of deposits in pipes was detd., the required solvents were brought to locations in 5-ton tank trucks with air compressor, acid circulating pump, and necessary gages, hose and fittings. Solvent was circulated through the pipe until tests indicated line was clean. Inhibited HCl generally used with wetting agents, and foam control and silica-removing agents. Cleaning restored original carrying capac. of pipelines.—*R. C. Bardwell.*

Earth Pressures on Pipes in Deep Trenches. B. W. Sutherns. Wtr. & Wtr. Eng. (Br.) **50**:118 (Mar. '47). In order to compare results with others, wt. of soil has been taken at 110 lb./cu.ft. Up to and including depth of 10′ on 48″ pipe in 5′ wide trench full earth pressure is taken as loading on pipe. Taking Secs. a and b in figure there will be no difference in load on pipe. By adopting c, load on pipe can be considerably reduced. Simple formula which will give approx. pressure, always on safe side, as compared with described tests is: $P = \frac{wh^{0.87}}{144} + 7.5$

where P = pressure on pipe in psi.; h = depth to top of pipe, ft.; w = unit wt. of fill material. Tests extended over more than 10 yr. showed, generally, that after first few months pressures were gradually increasing for first 6 yr., while for next 5 yr. there were no significant changes. Another formula offered is: $P_v = \gamma H_t - \dfrac{2S_1H_t}{D}$ in which P_v = vertical pressure on top of tunnel in psf.; γ = unit weight of overburden taken at 125 lb./cu.ft.; H_t = depth from ground surface to crown of tunnel; S_1 = product of avg. vertical shearing resistance of clay (300 psf.) and constant C_1, which is 0.84 for first few months down to 0.03 for final equil. after approx. period of 5 yr.; and D = diam. of tunnel. Timoshenko gives for collapsing pressure on pipes $P_c = \dfrac{Eh^3}{4(1-\mu^2)R^3}$ in which P_c is collapsing pressure in psi.; E is modulus of elasticity of pipe material; $h = t$ = thickness of shell; μ is Poisson's ratio, taken as 0.25; and R is mean radius of pipe. Majority of tests show that early loadings on pipes in deep trenches at all depths to 100–110′ are less than those due to static head. Loads, in most cases, steadily increase during 5 yr. gradually reaching pressure due to total depth of overburden.—*H. E. Babbitt.*

Pipe Repairs by the "Freez-Seal" Method. E. G. B. Gledhill & T. N. Young. Wtr. & Wtr. Eng. (Br.) **50**:140 (Mar. '47). "Freez-Seal" equip. has been designed for use principally in connection with repair of pipes and fittings and is particularly applicable to repair of water service pipes and stopcocks. Now, if water service fails anywhere, necessary to cut off water from service pipe concerned. This is done by shutting valves on main, and main and service must be emptied or partly emptied. This puts consumers to inconvenience and is source of annoyance. Main may become contamd. When work is finished water has to be turned on again carefully. With use of Freez-Seal equip. all such annoyances are elimd. Equip. based on principle of formation of ice plug in pipe to be repaired. One type makes use of small, portable mech. refrigerator. Flow from damaged section of pipe is stopped. Ice plug forms gradually in pipe as hollow plug free to expand both radially inwards and along axis of pipe in both directions. Time taken to freeze service pipes depends on nature of material of pipe and other factors. It may vary as follows: ½″, 3–6 min.; ¾″, 6–9 min.; 1″, 9–15 min. Saving in labor cost over other methods varies between 62 and 108%.—*H. E. Babbitt.*

Asphalt Lining of Small Pipes in Place Is Demonstrated. Anon. W. W. Eng. **100**: 360 (Apr. 2, '47). British process of electroplating pipe by passing current through 100′ lengths filled with bitumen compd. in water soln. described.—*Ed.*

Rising Mains—Most Economic Diameter. Douglas Bernhard Smith. J. Inst. Civ. Engrs. (Br.) **26**:534 (Oct. '46). Let c = cost per chain of pipe, in pounds; D = diam. of pipe in in.; e_m = eff. of motor, as decimal; e_p = eff. of pump, as decimal; f = sinking fund payments, in £ per cent per yr.; G = gpm. (Imp.) in rising main; H = friction head in ft. of water; k = constant depending on price per chain of pipeline compared to value given by empirical rule $c = 3D$; L = length of rising main in yd.; l = depn. on pipeline, in £ per cent per yr.; p = price of electricity, in d. per unit; r = rate of interest on capital, in £ per cent per yr.; T = time for which pump will operate, in hours per yr.; and y = total annual charges. Using Thomas Box formula: $H = (G^2L) \div (3D)^5$; horse power delivered by motor = $(10GH) \div 33{,}000e_p$; annual running cost, in pounds, is $(G^3LTp) \div (257{,}984{,}000e_pe_mD^5)$; annual expenditure for interest, sinking fund and depn. is $(r+f+l)(3kLD) \div 2200$; then total annual charges, y, is the sum of the above annual costs. Differentiating y with respect to D and equating to zero:

$$D = \frac{\sqrt{G}}{6.4252}\sqrt[6]{\frac{T_p}{e_pe_m\,(r+f+l)k}}$$

Limitations of Box formula are appreciated, so that formula deals only with pipes between, say, 4″ and 18″ diam. For conditions in Victoria, Australia, it is found that most economic diam. varies between about $\frac{1}{3}\sqrt{G}$ and $\frac{2}{3}\sqrt{G}$, and usually is $\frac{1}{2}\sqrt{G}$ leading to veloc. of about 2 fps. in all sizes of pipe.—*H. E. Babbitt.*

First Steel Radial-Cone Water Tank Constructed in Canada. Anon. Wtr. & Sew. (Can.) **84**:12:27 (Dec. '46). Township of Scarborough, Ont., all-welded tank supported on eight 42″ tubular steel columns and 8′ central riser enclosing 14″ inlet-outlet. Capac. 0.5 mil.gal., diam. 67′, effective depth 25′, top

water el. 115′ above ground. Appurtenances include 16″ c-i. pipe to distr. system, 16″ altitude valve with elec. solenoid remote control, and telemeter which transmits pressure to recorder in pumping station some distance away. Inside tank just above water line is wooden ceiling for frost protection. Cost about $75,000.—*R. E. Thompson.*

Build New 750,000 Gallon Water Tank at Hamilton (Ont.). ANON. Eng. Cont. Rec. (Can.) **60**:3:98 (Mar. '47). Mountain district has area of 925 acres and 11,000 pop., entirely residential, consumption being 1–1.2 mgd., about 115 gpd. per capita. Elevated tank of 90,000-gal. capac. replaced by welded radial-cone bottom tank with ellipsoidal roof. Diam. 82′, range in head 25′ and max. water el. 79′ above foundation. Central riser 8′ diam., with 20″ inlet-outlet in bottom, and 12 cylindrical supporting columns 4′ diam. Flow regulated by 16″ altitude valve and el. transmitted to recorder in booster station supplying tank. Pressure in area 30–60 psi., and in booster station 175 psi. City supply derived from Lake Ontario, high-lift pumps adjacent to filter plant delivering water to 11-mil.gal. reservoir.—*R. E. Thompson.*

Natural Hot Water Utilized for Household Heating. H. R. VINSON. W.W. Eng. **100**: 462 (Apr. 30, '47). Wells at Boise, Idaho, deliver water at 171°F. for swimming pool and domestic hot water and heating use.—*Ed.*

Water Works Reservoir Cleaned by Bulldozer. GLENN DUNCAN. N.Y. State Water Wks. News; Pub. Wks. **77**:37 (Nov. '46). Water works reservoir at Northville, N.Y., cleaned in Aug. '46 with assistance of bulldozer. This reservoir approx. 400′ by 1500′ in size, and some 3′ of silt and debris removed in 4 days with 5 men working. Bulldozer rented for 3 days at cost of $40 per day. Bulldozer, following receding water line, used to push accumulated material forward into channelway, where it was sluiced through mud pipe with water from upper reservoir. All banks flushed with 500 gpm. mobile fire pump and hose.—*P.H.E.A.*

PUMPS AND RELATED EQUIPMENT

Special Cooling Arrangement for Pump Engine at Charlottetown (P.E.I.). W. S. LEA. Wtr. & Sew. (Can.) **85**:1:15 (Jan. '47). Temp. of municipal driven-well supply, 50°F. almost constantly, considered too low for cooling water for oil engine driving 2-mgd. centrifugal pump. Pump dischg. line increases from 8″ to 12″ inside pumping station, and by using 2 increasers, 8 × 10″ and 10 × 12″, sufficient veloc. head recovered to circulate required cooling water from 12″ main through heat exchanger and back to 8″ pump dischg. Heat-exchanger consists of 6′ piece of 10″ pipe, fitted with central separator plate and Cu tubes through which water from cylinder jackets circulates and around which cooling water circulates. Since both engine load and water temp. const., control valves, once set, do not require adjustment. Advantages include: (a) no water wasted nor to be disposed of, (b) optimum temp. in engine jackets, (c) jacket walls clean as cooling water recirculated and make-up insignificant.—*R. E. Thompson.*

Unique Propeller Pump Installation Increases Flow in Gravity Water Tunnel. DEWEY M. RADCLIFFE. Eng. News-Rec., **136**:724 (May 2, '46). Greatly increased capac. obtained from existing water supply tunnel at Washington, D.C., by installation of variable-pitch propeller-type booster pump. Unit designed for high eff. with wide range in head and output of 0–150 mgd. Considered first of its type in this country, installation is believed to offer advantages for other municipalities obtaining their water supplies through intake tunnels. Article illustrated with charts, photograph, and installation design sketches. It includes discussion of selection of most suitable unit, control of pump, and performances obtained.—*P.H.E.A.*

Renewal and Extension of Pumping Machinery for the Metropolitan (London) Water Board. M. R. JAMES JR. J. Inst. Civ. Engrs. (Br.), **26**:432 (Oct. '46). Reviews 7 principal improvements in pumping facilities for Metropolitan London constructed during last 45 years since formation of Metropolitan Water Board to acquire works of 8 metropolitan water companies and 2 urban dist. councils. Also gives complete pumping cost data for 19 pumping stations. System of purchasing fuel on basis of calorific value begun in 1911 on basis of fuel testing experi-

ments 1909–1911 at Univ. of Illinois. Consumption: 1903, 254 mgd. [converted to U.S. gallons]; 1919, 321 mgd.; 1939, 376 mgd. Per capita consumption 1881–1903, 38 gpd., 1903–1932, 48 gpd. *Source of Supply.* ⅔ River Thames, ⅙ R. Lee, ⅙ deep wells. River water settled, filtered, sterilized. Pumping heads 100–350′. Well water chlorinated. 7 separate plant installations reviewed in much detail [only unusual features or significant departures from U.S. practice abstracted herein]. Selection of type of pumping equip. based on comparative ann. costs for steam turbine and reciprocal units (both triple expansion and uniflow), diesel and in some instances producer gas and purchased power. Choice of type of plant based on 7 considerations: (1) magnitude of duty, (2) load factor and nature of variation, (3) deg. of reliability required, (4) rel. prices of fuel, (5) cost of labor and repairs, (6) first cost of machinery and (7) expected life of plant. Where intermittent operation required, total load low and reliability necessary, oil engines considered best. Where 1 oil engine required for continuous duty, 2 stand-by units considered necessary, one available for duty while the third may be down for repairs. Unusual type of unit used for low head raw water service is Humphrey pump using producer gas mfd. at plant. 5 units installed prior to 191 totalling 216 mgd. capacity. Gas and air

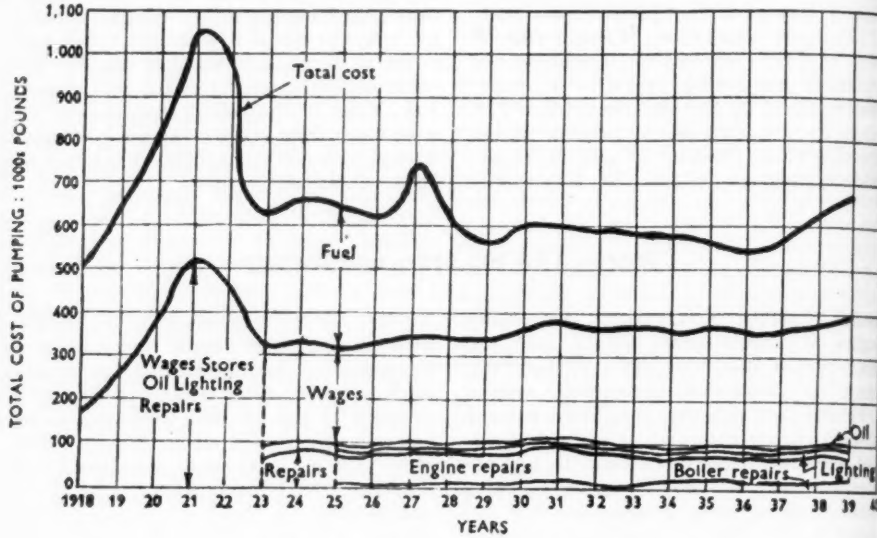

FIG. 1. Actual Annual Costs of Pumping

Purchased power not considered in largest installation because (1) more economical operation could be obtained in sizes involved using self-contained plant and (2) because considered undesirable that board should depend entirely on another authority over whom it had no control for the supply of power to its largest pumping station. Significant that earlier installations were triple expansion predominantly with steam turbine used in some for peak loads and stand-by. Latest and largest installation (1939) is steam turbine. Some plants diesels, however. Purchased power used in stations where absolute reliability not essential and in booster service where automatic operation desirable. mixed in combustion chamber above surface of water being pumped. Mixture ignited by spark plugs forcing water out. The subsequent surging of water in chamber with suction supply being admitted through check valves make unit continue to function as internal combustion engine delivering water against low head. Avg. age of plants weighted on W.H.P.: as of 1943, 24 yr.; 1939, 22.5 yr.; 1925, 36 yr. Improvements resulted in reduction in Btu. per water hp.-hr. from 45,000 in 1918 to 32,000 in 1941. Capital charges based on annual payment of sinking fund plus interest for life of installation. Buildings given same life as equipment. Fig. 1 shows actual annual costs of pumping

Type of Plant	Life yr.	Interest Rate Before 1932 %	After 1932 (Assumed) %
Reciprocating steam with turbine stand-by	40	5	3½
Steam Turbine	25	5	3½
Boilers	40	5	3½
Oil Engines	25	5	3½
Uniflow Engines	25	6½	3½

Discussion following paper indicates thought being given to effect of changing value of money during inflation and deflation periods on the eng. anal. and ann. cost evaluations for investments in long life projects typical of water works. No indication of crystallized opinion given on these matters which might characterize Br. eng. thought.—*V. C. Lischer.*

Large Pump Drives for Water Works. Anon. The Engr. (Br.) **180**:331 (Oct. 26, '45). Indus. demands for water in Rand, South Africa, have necessitated constr. of 2 new pumping stations, one at Zwartkopjes and other at Vereeniging. Both stations required to handle daily output of 40 mil.gal. (Imp.) against considerable head, involving unusually large pump drives. Zwartkopjes station worked with 2 pumps, each delivering 20 mgd. (Imp.) to height of 1150′. They are driven by Bibby flexible couplings, by 6500-hp., 11-kv., 1490-rpm., slip-ring motors. On official test 2 motors found to have effs. of 96.09 and 95.94%, at power factor of 0.895 in each case. Vereeniging station also consists of 2 duplicate pumps, delivering same quant. as at other station, but delivery height only 530′. Accordingly pumps smaller and require motors of lower capac. They are rated at 3000 hp. 11 kv. and 744 rpm.—*H. E. Babbitt.*

Reservoir and Pumping Station With Special Features. André Brisset Des Nos. Wtr. & Sew. (Can). **84**:3:27 (Mar.'46). Completed in '42, Côte-des-Neiges reservoir and pump. sta. serve districts formerly supplied by Montreal Water and Power Co., before system acquired by city in '27. Old sta. and reservoir abandoned. New sta., tendered price $45,659.57, pumps water from reservoir into Westmount distr. system, with demand of 1 mgd. Old 40,000-gal. steel cistern, connected to system through valve normally closed, supplies system when pumps not operating, valve opening and closing at pressures of 60 and 88 psi., resp. Architecture early French-Canadian to harmonize with residences. Three pumps, of 1-mgd. capac. each against 180′ head, driven by induction motors. Automatic cone valves, which can be operated manually, provide protection against flooding in event of pump stoppage or main breakage. New reservoir, tendered price $281,288.54, supplied through 34″ reinforced concrete main 9000′ long from McTavish pump sta., 275′ lower in el., by 15-mgd. pump. Consumption in district served 7 mgd., 4% of Greater Montreal consumption. Water depth 18′ and total capac. of 2 sections 7.5 mil.gal. Enclosing reinforced concrete wall 2′ 3″ from reservoir wall protects adjoining property against seepage. Baffle walls in each section ensure circulation. Concrete roof covered with 3′ 4″ earth. Air vents, 10″ diam., 4 in each section and rising 18″ above lawn, provide ventilation.—*R. E. Thompson.*

Water Wheels and Wood Pipes. F. W. Robins. Wtr. & Wtr. Eng. (Br.) **49**:183 (Apr. '46). Until 16th century water supply mainly gravitation and wells. In 1573, at Chester, Eng., there was projected new works for constant supply at High Cross including water wheels at Dee Bridge, lead pipes, and distr. of river water to houses. At end of 17th century Sir Thomas Lidiard agreed to provide Corp. of Rochester supply of water through lead or wooden pipes. In 1682 Rannequin, French engr., installed water wheel pump at Pont Notre Dame, Paris, to supply fountains at Versailles, in which he employed 14 water wheels and 253 pumps arranged in 3 lifts. In 1692 Scorrold installed at Derby, Eng., water wheel, water house and laid elm pipes under 99-yr. lease at annual rental of £3. Altogether last 10 years of 17th century and early years of 18th saw marked progress in water works installations. Improvements were introduced at London Bridge during 18th century, including means of raising and lowering wheels with tide. Water wheels remained in use in other cases well into 19th century—at Bridgenorth until 1857. Several were installed in U.S. where first public water works installed at Bethlehem, Pa. Wood pipes with some lead continued to be used during greater part of 18th century. Poln. rampant. In 1809 meeting was called about bathing in New R. and 20 yr. later reference in print to "the oozings of common sewers, dead dogs, Ophelias and other New River etceteras."—*H. E. Babbitt.*

Appliances for Raising Water—A Historical Sketch. C. S. Youatt. Wtr. and Wtr. Eng. (Br.) **49**:29, 74 (Jan., Feb. '46). Some of earliest known methods of raising water in use today. *First stage of development.* Carrying water from streams by means of open vessels, and raising water by movable vessels to which force was applied. *Second stage.* Pumps operated by suction. *Third stage.* Pumps operated by action of sliding plunger in some form upon water column. These include general classes of rotary and semi-rotary displacement pumps, jet pumps, air-lift and similar pumps, and pumps of hydraulic type. *Fourth stage.* All those pumps wherein driving element rotates about axis without any form of reciprocating motion. These comprise centrifugal pumps, axial flow pumps, mixed flow pumps, and pumps of water ring type. One of earliest of appliances used is probably basket, and similar vessels, operated by one or more men. Simple basket slung between 2 ropes, after dipping was swung to throw water to desired place. Where greater lift required, two or more baskets arranged in cascade. Another simple affair, limited in height of lift, was gutter or Jantu of early Christians. Arising from these early appliances comes tympanum. Reference must be made to screw pump, said to have been invented by Archimedes, about 250 B.C. Various forms of "chain of pots" came into being, contrivance following more simple cord and bucket in well, again mainly to introduce continuous action. As wells dug deeper, animal power used. Joseph's well, near Cairo, 300′ deep. In 1511 A.D. a German used fire bellows and attached suction pipe to intake opening, water being delivered at operating level. Development of pumps of third stage, frequently styled "force" pumps, long in time and remarkable in variations. In 1405 A.D. crank first shown in drawing by Konrad Myeser. Single-acting plain plunger displacement pump, due to Sir Samuel Moreland, 1675, and double-acting piston types rapidly came about. Application of steam mainly due to Newcomen, probably in 1712. Chief effort to reduce pulsations of discharge from displacement pumps is rotary pump. In jet pumps flow continuous. Hydraulic ram operates by kinetic energy of flowing water being used to force portion of supply to higher level. Centrifugal pump with origin in 17th century forerunner of familiar single-impeller type. Of these earliest attributed to Euler in 1745, McCarty 1830, and Appold in 1850. Development of single-impeller pumps along line of large discharge against relatively low head at low speeds, and also at high speed for direct coupling to motors or turbines. No great advance made in multi-stage pumps until 1875 when Prof. Osborne Reynolds conceived idea. Manufacture of this type of pump first developed by Mather and Platt, Ltd. Troubles with thrust satisfactorily overcome in 1910. For low head duties axial flow pump has applications for large dischg. Manufactured for dischg. up to 132,000 gpm. (Imp.). Bucket, probably leather, probably early means of fire extinguishing. Later single hand syringe derived from suction and force pump used. Double-cylinder machine developed later worked from 2-man lever on wheeled contrivance. Then came well-known steam fire engines and, within recent years, centrifugal pump with high speed petrol engine and self-propelled high speed vehicle.—*H. E. Babbitt.*

Automatic Pumping Plant Controls Center in Eight-Panel Switchboard. A. V. Lynn. Eng. News-Rec. **139**:62 (Jul. 10, '47). Automatically controlled pumping plant at South San Francisco, Calif., reduces costs by utilizing off-peak power and eliminating necessity for constant presence of operators.—*Ed.*

CHEMICAL ANALYSIS

New pH Indicators for Determination of Total Alkalinity in Water—Disodium 4,4′-bis *p*-dimethylaminophenylazo)-2,2′-stilbenedisulfonate and Disodium 4,4′-bis (*o*-tolyltriazeno)-2,2′-stilbenedisulfonate. Michael Taras. Anal. Chem. **19**:339 ('37). Prepn. of 2 new indicators of disazo-stilbeneaminedisulfonate series described. Disodium 4,4′-bis (*p*-dimethylaminophenylazo)-2,2′-stilbenedisulfonate (**I**) exhibits color change from pale purple (pH = 5.0) to blue with violet tinge, (pH = 4.0). Disodium 4,4′-bis(*o*-tolyltriazeno)-2,2′-stilbenedisulfonate (**II**) changes from deep yellow to max. muddiness in same pH range. Since carbonate concns. below 250 ppm. exhibit equivalence points in pH range of 5.0–4.5, whereas first visible indication of methyl orange transition occurs at pH of 4.5, pH range of these new indicators makes them more admissable for detg. total

alky. I can also be used in titration of yellow-colored solns. where bluish violet reflected back as deep green. In 100-ml. vol., 2 drops of 0.1% soln. of I ample for titrimetric purposes; 5 drops of 0.5% soln. of II required. No deterioration in either indicator evident after year's standing. Anal. data presented showing successful application of both indicators to detn. of total alkalinities in synthetic Na_2CO_3 solns. ranging from 50 to 500 ppm. as well as to Detroit water (75–87 ppm.). Data obtained from detns. in solns. having color of 70 also included.—*C.A.*

New Method for Colorimetric Determination of Calcium. A. BARRETO. Rev. Quím. Ind. (Brazil) **14**:163:18 ('45). In method for colorimetric detn. of calcium, 100 ml. of 0.15% soln. of chloranilic acid added to 100 ml. of soln. contg. not more than 0.01% calcium oxide, free from iron and acidified with acetic acid, in 500-ml. flask. Flask shaken and allowed to stand for 1 hr. and its contents dild. to exactly 500 ml. Filtered portion of soln. compared in colorimeter with sample contg. no calcium. Difference in color corresponds to amt. of chloranilic acid which has combined with calcium to form insol. ppt. Chloranilic acid may also be used for detg. calcium gravimetrically, provided that iron, barium and strontium absent.—*W.P.R.*

Use of a Selective Electrode for Determining Anions in Aqueous Solutions. D. MITOFF & E. SCHAAF. Z. Anal. Chem. (Ger.) **127**:139 ('44). Content of chlorine in aq. soln. may be detd. by connecting in series electrode of silver and silver chloride, soln. to be analyzed, and a calomel cell; the emf. then measure of content of chlorine. Results obtained by this method in samples which contained 43.5 to 83.5 mg. of chlorine per l. agreed within 1 mg. with values obtained by titration method.—*W.P.R.*

New Method of Estimating Calcium, Barium, Strontium and Zinc. A. BARRETO. Rev. Quím. Indus. (Brazil) **15**:165:16 ('46). Chloranilic acid forms insol. salts with calcium, barium, strontium and zinc and in aq. soln. forms strong color even at high dilns. Method for detg. calcium, barium, strontium and zinc based on detg. vol. of chloranilic acid which can be decolorized by sample of known size. Sample must be free from iron and in detn. of zinc, ammonia should be absent.—*W.P.R.*

Colorimetric Determination of Fluoride. D. MONNIER, Y. RUSCONI & P. WENGER. Helv. Chim. Acta (Swiss) **29**:521 ('46). Method for detg. fluoride based on fact that fluorine will bleach violet color produced when ferric iron added to 5-sulfosalicylic acid. To make test, soln. to be analyzed added to soln. contg. ferric chloride, ammonium chloride, sufficient hydrochloric acid to bring pH value to 3, and sulfosalicylic acid, until intensity of color has been reduced to std. tint.—*W.P.R.*

The Estimation of Iron in Water. D. J. BENGOLEA & F. D. AMATO. Rev. Admin. Nacional Agua (Arg.) **19**:111:195 ('46). In procedure recommended in *Standard Methods* of Am. Water Works Assn. and Am. Public Health Assn. for detg. iron in water, iron first oxidized completely to ferric state by potassium permanganate and then estd. colorimetrically by titration with potassium thiocyanate. Accurate results obtained by this method only if water free from clay contg. iron and if pptn. of dissolved iron does not occur. In authors' modification of this method, 10–15 mg. of sodium citrate per 250–300 ml. of water added before oxidation with permanganate and subsequent titration with potassium thiocyanate. Addn. of sodium citrate inhibits pptn. of dissolved iron and prevents iron from dissolving out of any clay which may be present in water, but does not interfere with reaction.—*W.P.R.*

A Photometric Adaptation of the α-Naphthylamine Method for Nitrites. E. I. WHITEHEAD. Proc. S. Dakota Acad. Sci. **23**:76 ('43). Detn. of nitrite by means of reaction with sulfanilic acid and α-naphthylamine may be adapted for use with Evelyn photoelec. colorimeter provided that sufficient time (60 min.) allowed to elapse between addns. of sulfanilic acid and of α-naphthylamine to sample to permit initial diazotization to reach completion. By using photoelec. colorimeter, necessity for prepg. color stds. for each set of samples avoided, and much greater concns. of nitrite can be accurately detd. than by visual comparison.—*W.P.R.*

Testing for Oxygen in Boiler Feed Water. K. M. GIBSON. J. Inst. Engrs. S. Africa **43**:21 ('44). In tests for D.O. in boiler feed water, samples withdrawn through black rubber tubing about 5′ long. Found that content of oxygen 0.5 ml./l., though not more than 0.2 ml./l. expected. When samples withdrawn through copper tubing avg. con-

tent of D.O. 0.1 ml./l. Further tests showed that when more than a few inches of rubber tubing used, especially at high temps., content of D.O. in water increased. Concluded that permeability of rubber to oxygen sufficient to introduce important errors when small quants. of oxygen, such as may be present in boiler feed water, are being detd.—*W.P.R.*

The Determination of Oxygen in the Presence of Sulfite. C. Janssen. Chem. Weekblad. (Holland) **42**:115 ('46). When Winkler method used to det. oxygen in boiler feed water contg. sodium sulfite, combination of oxygen and sulfite in equiv. portions catalyzed by manganous ion of manganous chloride added. Content of sulfite must therefore be detd.—*W.P.R.*

Determination of Small Quantities of Phenols in Water. Felipe Carlos Basavilbaso Rev. Obras Sanitarias Nacion. (Arg.) **20**:158 (Mar.–Apr. '47). Use of isoamyl alc. for extraction of colored compds. formed by reaction of phenols with Gibbs reagent elims. need of distn., thus simplifying procedure for detn. of phenols in water. Modified procedure as follows: *Std. Phenol Soln.* Dissolve 1 g. phenol C.P. (mp. 40°C) in 1 l. distd. water. Standardize as indicated in *Standard Methods for the Examination of Water and Sewage.* Concd. soln. quite stable. When ready to prepare stds., dil. 1 ml. stock soln. to 1 l. with distd. water. *Phenol-Free Distd. Water.* Add 10 to 20 mg. good qual. activated carbon per l. of distd. water, agitate and, after several hrs., filter through No. 42 Whatman filter paper in Büchner filter. If necessary, remove chlorine by boiling. *Manganous Sulfate Soln.* Dissolve 169 g. of $MnSO_4 \cdot H_2O$ and 10 g. $CuSO_4 \cdot 5\,H_2O$ in 400 ml. of water. Add 500 ml. of 2N HCl and make up to 1 l. with distd. water. *Sodium Hydroxide Soln.* Normal. *Buffer Soln.* Dissolve 40 g. of borax in 900 ml. of hot distd. water and make up to 1 l. *Indicator.* Dissolve 15 mg. of 2,6 dibromoquinonechlorimide in 10 ml. of ethyl alc. and add 0.5 ml. of 0.1N HCl. Soln. may be kept 2 or 3 days in amber-colored bottle. Daily prepn. recommended. For each detn., 0.20 ml. of this soln. may be used. Preferably, dil. reagent 1 to 10 with distd. water just before using and add 2.0 ml. of dil. soln. to each sample. Dil. soln. decomposes rapidly. *Isoamyl Alc.* Pure and colorless. *Glass Vials.* Flat bottom, 6 mm. id. and 10 cm. high with mark at 9 cm. Wide mouth bottles or 250-ml. Erlenmeyer flasks with ground glass stoppers. *Procedure.* Transfer 100 ml. sample to 250-ml. glass-stoppered container. Add 1 ml. $MnSO_4$ soln., stopper flask and agitate energetically. Add 2.5 ml. of *N*NaOH, mix, and add 10 ml. buffer soln. These addns. may be made on samples and prepd. stds. simultaneously. Add 2 ml. dil. indicator soln. while maintg. flask contents gently agitated. Stopper container and let stand 10 min. Disperse pptd. oxides of Mn by swirling contents of flask gently and let stand 10 min. Repeat operation 2 or 3 times. Stand 4 hrs., or overnight, add to each container 10 ml. isoamyl alc., agitate vigorously with whirling motion 20 to 30 secs. and let stand until layers separate. Transfer alc. layer to comparison tube with dry pipette. Fill to mark and compare with std. solns. treated in same manner as unknowns. A convenient set of stds. covers 0,2, 5, 10, 15, 20, 30, 40, 50, 60, 80 and 100 γ/l. phenol. Greatest precision obtained between 10 and 50 γ/l. Std. scale may be extended to 500 γ/l., but preferably dil. sample when phenol content exceeds 100 γ/l. Color comparisons made observing liquid in tube longitudinally against white background. Sepn. of alc. layer facilitated by previous transfer of layer with some water from flask to large test tube. Color of isoamyl alc. extracts unstable in strong light. Make readings shortly after alc. extraction keeping extracts away from strong light until ready for comparison. Advantages of proposed procedure: Direct, and avoids distn.; color, turbidity, and mineral compn. of sample do not interfere; simplicity permits handling many samples simultaneously; discounting reaction time, 30 samples can be analyzed in less than 3 hrs.; sensitivity of test about 5 times greater than *Standard Methods* procedure, thus avoiding need for concn. of samples low in phenols; precision at least as good as that in distn. procedure; gradation of color in stds. better than that obtained without alc. extraction; procedure satisfactory in presence of reducing substances and appreciable quants. of sulfates; applicable to different types of water without special pH adjustment and, therefore, suitable for routine detns. Aniline gives false positive test for phenol. Presence of aniline in sufficient amt. to interfere with test not likely in normal fresh waters. In aniline-contg. industrial wastes, phenol isolation by distn. necessary.—*J. M. Sanchis.*